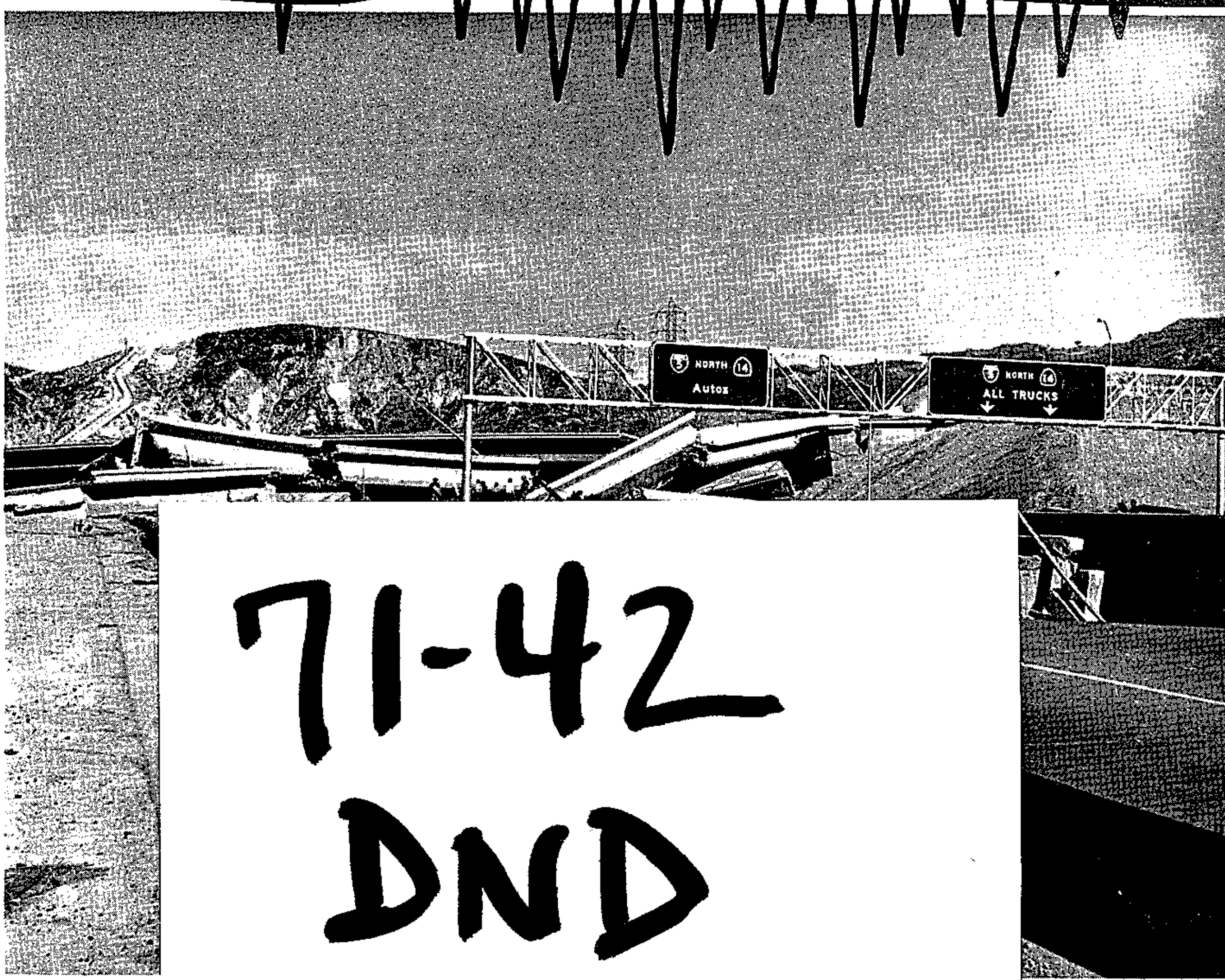
the San Fernando EARTHQUAKE

Feb. 9, 1971



STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

THE EFFECT ON STATE HIGHWAYS OF THE SAN FERNANDO EARTHQUAKE FEBRUARY 9, 1971

SEPTEMBER 1971

SUBMITTED PURSUANT TO SB 682

State of California

Business and Transportation Agency

Memorandum

To : Mr. James A. Moe
Director of Public Works

Date: September 10, 1971

File : 07-LA-5
Earthquake Report
07214 - 287800

From : Department of Public Works—Division of Highways

Subject: Earthquake Report

The accompanying report summarizes the effects of the February 9 San Fernando Earthquake on State Highways and was prepared pursuant to the requirements on Section 1 (b) and Section 2 of Senate Bill 682.

Included in the report is a description of the earthquake as a seismological event and its effect on the various elements of the freeways in the affected areas. Also discussed is the management of traffic over the vital arteries connecting the Los Angeles metropolitan area to the rest of the State.

Recommendations are offered for the restoration of damaged roads along with a program of contracts for both restoration work and completion of the two major interchanges which were underway at the time of the earthquake.

Finally, recommendations for design of freeways in seismic areas are proposed. The list of references and appendix contain additional sources of information relative to the earthquake.

An overall summary of the report is contained in the Introductory Chapter, pages 2 through 8.

J. A. LEGARRA
State Highway Engineer

FORM H-AD 37A

CONTENTS

GLOSSARY

(Terms used in the Earthquake Report)

ACCELERATION	The rate of change of velocity; a measure of ground shaking.
ACCELEROMETER	A type of seismometer which measures acceleration of the ground movement.
AFTERSHOCK	An earthquake which follows a larger earthquake and originates at or near the focus of the larger earthquake. Generally, major earthquakes are followed by a large number of aftershocks, decreasing in frequency with time. Such a series of aftershocks may last many days or even months.
ALLUVIUM	A general term for sandy and gravelly sediments laid down in riverbeds, floodplains, lakes, fans at the foot of mountain slopes, and estuaries.
BEDDING PLANES	Planes of stratification or layering.
BEDROCK	A relatively firm, consolidated rock stratum which is not underlain by unconsolidated material.
BUTTRESS FILL	A supporting fill.

EARTHQUAKE	An earthquake is a vibration or oscillation of the ground surface by disturbance of the equilibrium of the rocks at or beneath the surface. When a series of earthquakes originate at or near a common focus and occur within a relatively short period of time, one of them (generally the one of greatest magnitude) is arbitrarily designated as the earthquake, and those preceding and following it are designated as fore-shocks and aftershocks.
EARTHQUAKE INTENSITY	A measure of the relative effect of an earthquake on man and his structures or works, commonly defined by a numerical value, according to the modified Mercalli Scale (see below).
EARTHQUAKE MAGNITUDE	A measure of the size of an earthquake, based upon instrumental records. The scale has been defined by Professor Charles Richter (see below), and is logarithmic. Therefore, every upward step of one unit (e.g. from 6.0 to 7.0) means multiplying the recorded amplitude by 10. The magnitude can also be related to the earthquakes energy. A one-unit increase in magnitude corresponds roughly to a 30-fold increase in energy.
EPICENTER (Noun)	The point on the surface of the earth directly over the focus of an earthquake.
EPICENTRAL (Adj.)	In the vicinity of the epicenter.
FAULT	A fracture or fracture zone in the earth's crust along which there has been displacement of the two sides relative to one another parallel to the fracture. The width may be from less than an inch to hundreds of feet or more, and the displacement may be from a few inches to many miles.

ACTIVE FAULT	A fault which has exhibited movement or seismic activity in historic times, or has displaced recent geologic formations.
INACTIVE FAULT	A fault along which no displacement of recent geologic formation has occurred, and which has exhibited no seismic activity within historic times.
FOCAL (FOCUS)	In seismology, the origin point of the first recorded waves of an earthquake. Generally believed to represent the position of the initial rupture of the rocks.
GEOMORPHIC	Pertaining to land forms.
LIQUEFACTION	A sudden large decrease in strength of a cohesionless soil. It is caused by vibration, shock, or other strain, and is associated with a sudden but temporary increase of the porewater pressure.
MODIFIED MERCALLI SCALE	A numerical scale for classifying the relative intensity of earthquakes according to observed effects at a particular location. Expressed as Roman numerals I through XII.
REFLECTED WAVES	Waves returned from a reflecting surface.
REFRACTED WAVES	Deflection of direction of waves when passing obliquely from one region of velocity to another.

RICHTER SCALE	An earthquake scale based on the measured energy release of an earthquake as determined by a seismograph. Expressed in Arabic numerals. See EARTHQUAKE MAGNITUDE.
SAND BOIL	A turbulent suspension of sand in water occurring at the exit point of upward flowing seepage.
SCARP (FAULT SCARP)	A steep face or cliff resulting from relative movement on a fault.
SEDIMENTS	Solid material, both mineral and organic, that is in suspension, is being transported or has been moved from its site of origin by air, water, or ice, and has come to rest on the earth's surface either above or below sea level.
SEISMIC	Earthquakes or earth vibration, as seismic disturbances.
SEISMICITY	Earthquake activity.
SEISMOGRAPH	Instrument with records seismic waves. Syn: DETECTOR.
SEISMOLOGIST	One who applies the principles of seismology to his work; e.g., oil exploration, earthquake detection, and analysis.
SLIDES (LANDSLIDES)	Mass movement of earth and/or rock under the influence of gravity. Relatively rapid as opposed to soil creep, which is a slow, continuous movement.

SLIPOUT	A form of landslide.
SLOUGHING	Minor slope failure.
SUBSIDENCE	The lowering or depression of the land surface.
TECTONIC	Related to the force and processes that deform the earth's crust.
TEMBLOR	An earthquake.
THRUST FAULT	A low dipping reverse fault.
TRANSLATIONAL SLIDE	Entire slide moving in the same direction.

ACKNOWLEDGEMENT

Appreciation is expressed to the many contributors to this report. Travis Smith and his staff of the Materials and Research Department contributed significant portions on geology and seismology. The extensive reports by Bert Bezzone and others of the Bridge Department were used verbatim in Chapters I and V. Paul Wagner and Walter Whitnack of Headquarters Design reviewed and reported on the pavement and drainage damage.

Many District 7 people contributed to this report, including John Webster of Materials Department, Jack H. Smith, Chester Shearer and William Myyra of Maintenance, Charles W. Ford, Raymond Cockrell, and Emory Price of Construction, Theodore Kawahigashi of Freeway Operations, Richard H. Laughlin and Harold Yamaguchi of Design C.

Additional research was also carried out by Neil Shaver of Press Information Office.

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J. A. Legarra, State Highway Engineer

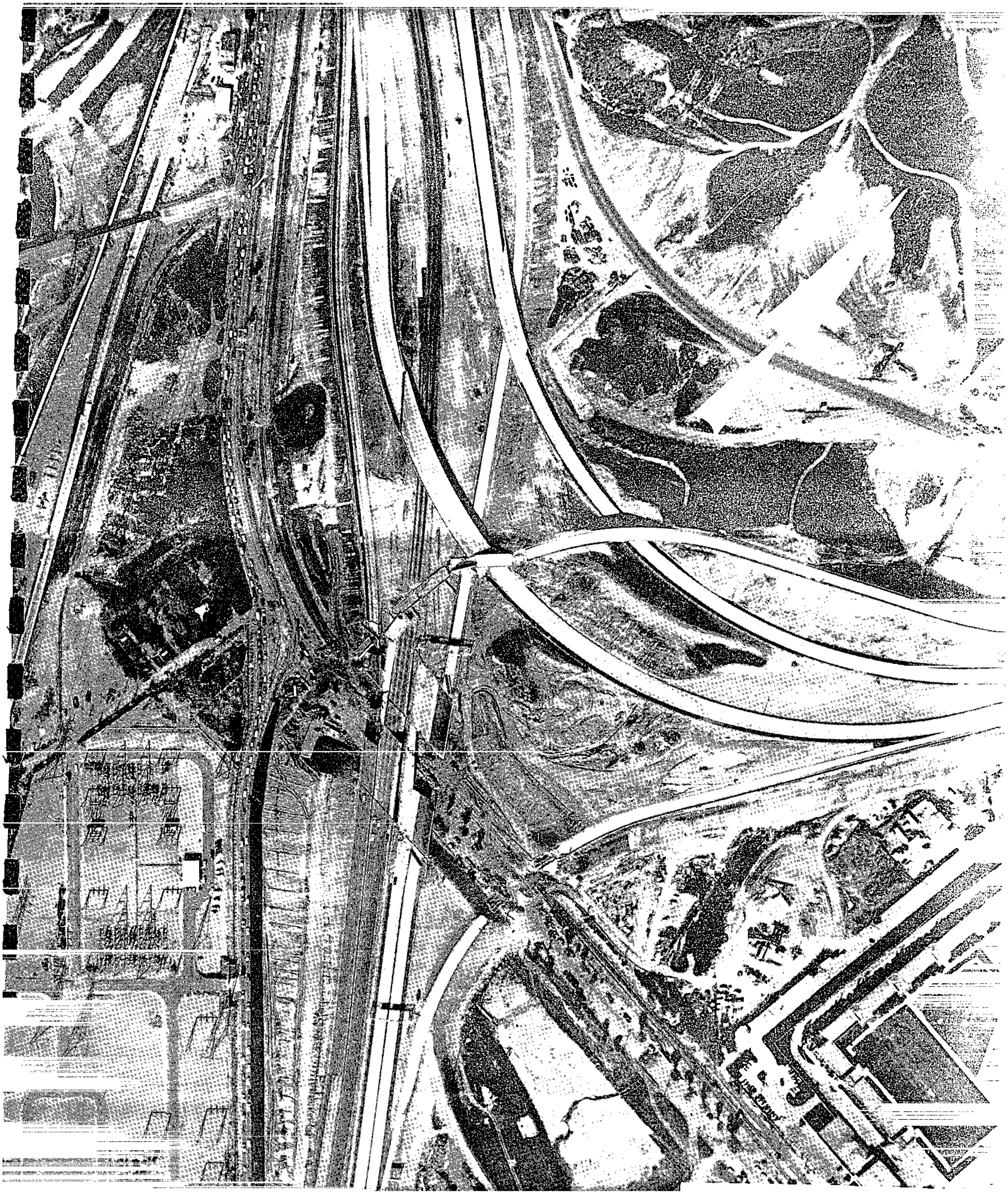
H. Ayanian, District Engineer

A. L. Himelhoch, Deputy District Engineer

Supervised by: A. D. Mayfield, Design C

Edited by: Richard G. Drosendahl, Design C

Assisted by: T. M. Berg, and his Project Design Group



AERIAL VIEW OF
Route 5/210 Interchange
February 11, 1971
(two days after earthquake

INTRODUCTION

I. OBJECTIVE
II. SUMMARY

INTRODUCTION

I. OBJECTIVE

The San Fernando earthquake of February 9, 1971 involved movement on minor faults considered inactive in recent time. Although the earthquake was of only moderate magnitude (6.6 Richter), the resultant ground shaking was the highest ever recorded. This unprecedented amount of shaking damaged and destroyed 15 million dollars worth of freeway facilities in the San Fernando area. Taking a perspective view, this was less than 3% of the total damage, public and private. Two people lost their lives on highways as a result of the quake.

The objective of this report is to present to the reader a survey of the earthquake and its effects on State Highways, and to propose a program of reconstruction, modification and future design policies for highway facilities.

II. SUMMARY

The San Fernando Earthquake centered in an area containing a number of major freeways and hundreds of freeway structures. Ground disruptions caused rupture or settlement of the freeway pavement in numerous places and 62 structures were damaged, six of which were beyond repair and were at least partially removed. This is the first time any State highway structure has been lost due to an earthquake.

The emergency provided a rigorous test of the ability of the Division of Highways to react to a disaster and restore traffic in a very short time. The necessity for coordination of effort by industry and all levels and functions of government was clearly demonstrated by this disaster. Without the coordination achieved in the aftermath of this quake the results could have been many times more tragic. The extreme damage to some of the structures served as a unique sort of laboratory in which full-scale bridges were tested to destruction. From this experience valuable lessons have been learned. Future seismic design theory will take into account information revealed by this quake.

The most severe damage was concentrated at two major interchanges within the devastated area, both of which were under construction at the time of the disaster. To preclude further construction until an adequate investigation had been made, Senate Bill 682 was passed and signed by the Governor authorizing the Department of Public Works to terminate the contracts.

Several emergency contracts were awarded to re-establish traffic patterns through the area, one of which provided a 6-lane detour of I-5 from Roxford Street through the 5/14 Interchange.

After extensive investigation, a series of contracts will be advertised to repair major and minor damage caused in the roadways and structures, and to complete the two interchanges.

There is no economically feasible way to build highway embankments to withstand this sort of disruption without damage. The investigations of the terrain in and around the area of damaged and destroyed facilities do not indicate a new location or alignment traversing the area would be any less vulnerable; consequently, the alignment will not be substantially changed. Modification of design details of structures, however, will be made to make them better able to withstand this violent abuse.

The seismic design criteria have been revised and all State nighway structures designed after the San Fernando Earthquake will contain many restraining and confining details which will make them more earthquake resistant. The entire State Highway System is being studied and structures identified for installation of restraining safeguards. Over the next few years, a program will be under way to provide this sort of protection in critical areas throughout the State.

Continuing long-term research is under way to develop a more sophisticated seismic design theory utilizing the vast amount of data generated by this earthquake.

1. Earthquake results

   In general, the underground facilities held up rather well. Cuts and fills and pavement suffered an amount of damage which might be considered as predictable under the forces involved. The bridges were obviously more vulnerable to the violent forces which shook them both horizontally and vertically.

2. Design Objectives

   A suggested general objective of earthquake-resistant design (applicable to any man-made structure) would be to survive a light-to-moderate quake undamaged; to survive a moderate quake with an acceptable amount of damage; and to survive a moderate-to-heavy quake without totally collapsing or jeopardizing the lives of motorists even though the structural damage may be beyond repair.

3. Peformance of existing facilities

   Prior to the quake the criteria used by the Division of Highways in the design of structures for earthquake forces were based on "Recommended Lateral Force Requirements" developed over a period of years by the Seismic Committee of the Structural Engineers Association of California. This specification was based on seismograph readings taken from the El Centro earthquake of 1940. The San Fernando quake's ground shaking was the highest ever recorded and was considerably in excess of the lateral forces for which the structures were designed.

Pavement failures were small enough to patch for emergency traffic, although extensive reconstruction will be required in the permanent restoration. The total cost of slide removal and slipout repair will be rather small. Most of the drainage structures are repairable.

4. Modification of Design Procedures

A survey and analysis of bridge damage was made immediately following the earthquake. As a result of the investigation, bridge details have been developed which will improve the resistance of structures subjected to seismic forces. These changes include improvements in such bridge elements as footings, columns, hinges, bearings and abutments. In addition, as an interim measure, earthquake factors have been doubled for structures founded on spread footings and have been increased by 2-1/2 times for bridges founded on piles.

5. Alignment

Recommendations concerning the routing of freeways in seismic area are contained in Chapter V-B and C, with the objective of mitigating damage. Present procedures for design of earthwork cuts and fills, pavement, and drainage structures are recommended for retention, subject to early consideration of routing in seismic areas. The pattern of damage sustained would not indicate significant changes in the approach to design of the roadbed. The structural section cannot be insulated from movements of the ground on which it rests. The forces in a major earthquake are too great to counteract with increases in strength of pavement slabs or drainage structures.

6. Reconstruction of Destroyed and Damaged Facilities

The investigation of the terrain in and around the damaged and destroyed facilities does not indicate a new location or alignment traversing the area would be any less vulnerable, consequently, the alignment will not be modified. Modification of design details of the structure making the bridge less vulnerable to damage will be made.

Temporary repairs, sufficient to handle traffic, were made as soon as possible after the earthquake. Permanent-type repairs are recommended to be accomplished in a series of contracts to be advertised as early as possible.

7. Completion of construction of Incomplete Facilities

Six major construction contracts underway on February 9, 1971, were affected by the earthquake. On three of these (07-011204, -022874, -033274), the damage was very slight and has been repaired. Under the provisions of Senate Bill 682 signed by the Governor July 7, 1971, (Appendix II), the contracts under way in the area are authorized to be terminated. In contract 07-035624, (LA-14, 126 - Granite Construction Company), approximately $450,000 damage occurred. The contractor did not choose to terminate, and the contract is proceeding toward completion as designed, except as modified by contract change order. Contracts 07-068314 (Guy F. Atkinson Company) and 07-068324 (Kasler Corporation and Gordon H. Ball, Incorporated) are in the process of being terminated. Upon completion of termination proceedings and preparation of revised plans, specifications, and estimates, the Division of Highways proposes to advertise for bids on new contracts. These new contracts will have essentially the same limits of work as the old contracts.

8. Review and Possible Modification of Facilities Throughout the State Highway System

A. Highway and Freeway Location and Plans

Early in the route location process, active and inactive faults should be mapped. A general assessment of the seismic risk of various areas within the study zone should then be prepared.

Consideration must be given to the location of major interchanges. They should be sited outside of heavily-faulted areas whenever feasible. Where seismic activity is highly probable, consideration should be given to avoiding complex multi-level interchanges in favor of simple designs with short span structures and maximum use of embankment.

Early recognition of seismic risk might lead the planner to modify alignment or grade in order to minimize high cuts, fills, and bridge structures in a given area. Where a freeway must pass through a highly seismic area, the best and safest plan will generally be the simplest: close to the original ground, with simple, square bridge structures.

B. Bridge Design

Improved bridge design details and increased seismic factors as previously described are being used in the restoration of the damaged structures, in future bridge designs, in modifying structures on going contracts to the extent practicable and to some extent in the modification of existing structures.

A program has been initiated to improve the earthquake resistance of existing structures which are particularly sensitive to large earthquake movements.

An important long-range recommendation is that continued cooperation be maintained with the various other agencies and organizations concerned with earthquake design. Among these are Structural Engineers Association of California, Earthquake Engineering Research Institute, Federal Highway Administration and Advisory Committees to the State Legislature.

C. Roadway Facilities

As discussed in Section II-4, above, present design standards for earthwork, pavement, and drainage facilities will suffice, subject to recognition of seismic risk.

D. General Recommendations

Additional expenditure for right of way and construction to make highways and freeways more earthquake resistant will have to be kept in balance with the amount of impact on the traveling public, if the facility may be put out of service following a disastrous earthquake. Also, the probable rate of recurrence at a specific location is often so infrequent as to make the value of additional expenditure questionable.

As a general practice, it would be expected that additional expenditures for earthquake resistant details would be a nominal portion of normal project costs when the site is in a known active fault area. Expenditures over that amount would not give assurance of resistance to major damage in a severe quake.

E. Prospects for the Future

Seismologists seem to be unanimous in warning that there are major earthquakes to come, within our lifetime, and within the economic and technological life of man-made structures. Milne and Davenport have stated that[1]

> "The probability that an earthquake will occur which can create acceleration amplitudes of sufficiently high values to cause damage, has been computed by two related but somewhat different methods. Almost all of California can expect to experience earthquakes which will cause damage according to these predictions."

and

> "The other way of expressing the risk is that nearly all of California can expect to experience accelerations greater than 10% gravity on the average once per 100 years. This acceleration is experienced more often than once in 50 years at many sites along the San Andreas Fault Zone. This level of earthquake activity is not reached elsewhere in the western United States."

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[1]See VI, Reference 3

In their treatise, Milne and Davenport portrayed charts[2] of both the "return period" in years, for an earthquake yielding acceleration of 10% gravity, and the acceleration, in percent of g, with a return period of 100 years. Both of these charts indicate a relatively high degree of seismic risk in California's metropolitan areas.

In a UCLA Master's Thesis (1970), Neil Keith Anderson proposed a method of forecasting earthquake shaking intensity. This method relates to geographic location, and compiles the composite risk due to all faults.

Along with other research being done, these methods have potential for use in developing a more rational basis for earthquake-resistant design. A State-wide map of seismic probability zones should be prepared.

In conclusion, the prospects look hopeful for developing rational assessment of seismic risk, estimation of the forces involved, and improved engineering design of our structural creations. However, prediction of the time and place of the great seismic events will probably continue to elude the scientists for some time to come. We can only do our best to be prepared.

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[2] See Appendix I

CHAPTER I

THE SAN FERNANDO EARTHQUAKE

I. THE SAN FERNANDO EARTHQUAKE

A. Resume of Damage to Highways and Freeways

The heaviest concentration of road damage occurred at the Route 5/210 Interchange and along the completed five-mile portion of Interstate Route 210. Portions of Interstate Routes 5 and 405 and State Routes 2 and 14 also sustained moderate to heavy damage.

Structural damage was severe. Three major bridges completely collapsed while several others were damaged to the point of making them unsafe for public use. Other bridges received minor damage which did not affect their structural integrity. The number of bridges that either collapsed or sustained extremely heavy damage was small, however, when compared to the total number of structures in the affected area.

Road damage occurred in several forms including subsidence of fills, separated pavement slabs, buckled pavement, failures in cut slopes and fills, and settlement at bridge approaches. Although much of the damage was not as serious as it first appeared, major reconstruction will be required in some locations to restore the facilities to pre-quake standards. Preliminary estimates of total damage to State highways is $15 million.

B. Geologic Data

Map No. 2 shows the location of the major faults in the vicinity of San Fernando, and their relationship to geographic features.

The area affected by the earthquake lies in the northwestern San Fernando Valley immediately south of the San Gabriel Mountains in the Transverse Ranges of Southern California. The following chart summarizes the basic foundation conditions and types of construction.

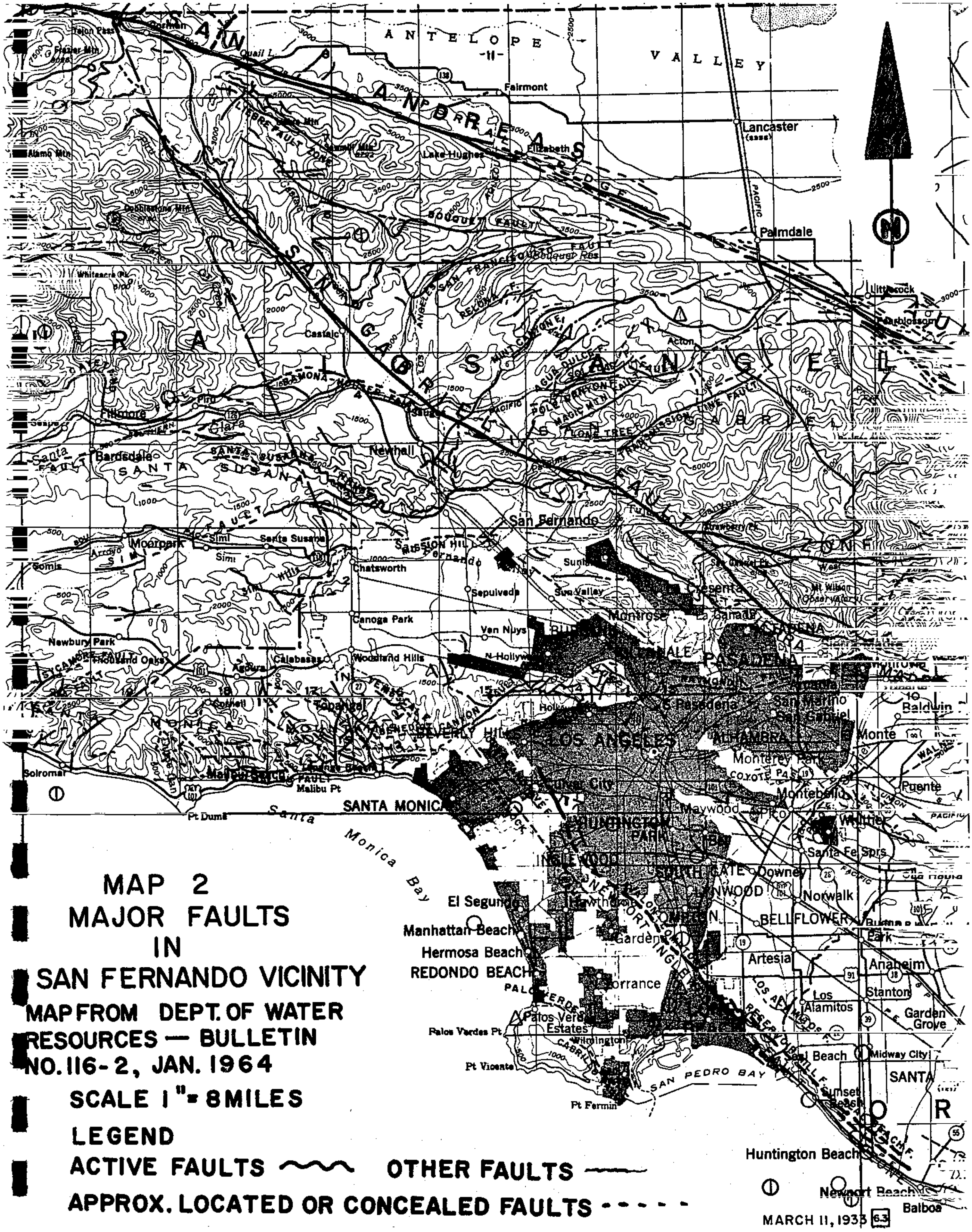
Freeway or Interchange	Principal Foundation Condition	Principal Type Of Construction
5/14	Bedrock, marine sediments. . .	Cut
5/210	Alluvium	Fill
5/405	Bedrock, continental sediments	Cut
Route 210	Alluvium . . . . (Minor amount of bedrock, continental sediments). . . .	Fill Cut
Route 5 (South of 210)	Alluvium . . . . (Minor amount of bedrock, continental sediments). . . .	Fill Cut
Route 5 (North of 210)	Bedrock marine and continental sediments . . . . (Minor amount of alluvium) . .	Cut Fill

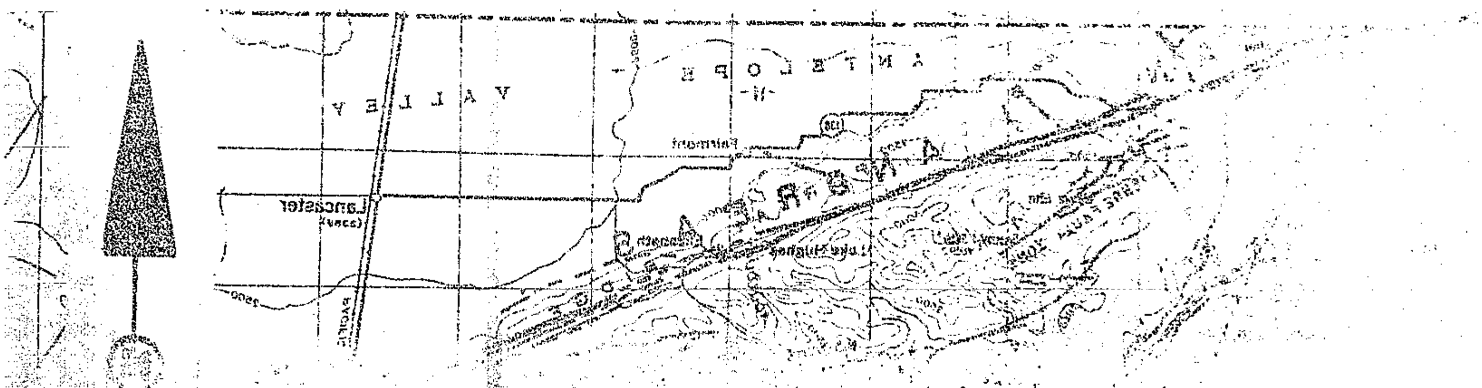
It should be stressed that all major transportation corridors in their natural and historic development are linked to geographic and geomorphic features which are in turn a reflection of the geologic structure of a region. Transporation corridors develop because of, not in spite of, "adverse" geologic construction.

The following freeway locations are in the vicinity of known faults:

> The 5/14 Interchange lies in the proximity of the Santa Susana fault zone;
>
> Route 210 parallels the Sierra Madre fault zone; and the
>
> 5/405 Interchange is located near the Mission Hills fault.

Roadway damage as a result of actual fault rupture was minor and highly localized. The proximity to a fault does not appear to be the most significant factor. The degree of freeway damage does appear to have some correlation with the foundation conditions and


ANTELOPE
VALLEY
SAN ANDREAS
RIDGE
Tejon Pass
Gorman
Quail L.
Fairmont
Lancaster
Lake Hughes
Elizabeth
Alamo Mtn
Palmdale
BOUQUET FAULT
SAN GABRIEL
SAN FRANCISQUITO FAULT
Bouquet Res
Whiteacre Pk
Littlerock
Castaic
Acton
SAN GABRIEL
Fillmore
Piru
Bardsdale
SANTA SUSANA
Newhall
LONE TREE
San Fernando
ZONE
Moorpark
Simi
Santa Susana
MISSION HILLS
Somis
Chatsworth
Sepulveda
Sun Valley
Montrose
Canoga Park
Van Nuys
Newbury Park
Thousand Oaks
Agoura
Calabasas
Woodland Hills
N Hollywood
PASADENA
Sierra Madre
San Marino
San Gabriel
Baldwin
Topanga
BEVERLY HILLS
LOS ANGELES
ALHAMBRA
Monte
Monterey Park
Solromar
Malibu Beach
Malibu Pt
SANTA MONICA
Pt Dume
Santa Monica Bay
Montebello
Puente
Maywood
Whittier
HUNTINGTON PARK
INGLEWOOD
SOUTH GATE
Santa Fe Sprs
Downey
El Segundo
LYNWOOD
Norwalk
Manhattan Beach
Hawthorne
BELLFLOWER
Gardena
Hermosa Beach
Artesia
REDONDO BEACH
Torrance
Anaheim
Los Alamitos
Stanton
Garden Grove
Palos Verdes Estates
Palos Verdes Pt
Wilmington
Pt Vicente
Seal Beach
Midway City
SANTA
SAN PEDRO BAY
Sunset Beach
Pt Fermin
Huntington Beach
Newport Beach
Balboa
MAP 2
MAJOR FAULTS
IN
SAN FERNANDO VICINITY
MAP FROM DEPT. OF WATER
RESOURCES — BULLETIN
NO. 116-2, JAN. 1964
SCALE 1" = 8 MILES
LEGEND
ACTIVE FAULTS
OTHER FAULTS
APPROX. LOCATED OR CONCEALED FAULTS
MARCH 11, 1933 6.3



transmissibility of seismic shock waves in the underlying rock and soil. The severity and geographical distribution of earthquake damage throughout the northern San Fernando Valley/Saugus/Newhall area attests to this.

C. Magnitude

The San Fernando earthquake of February 9, 1971, was the most damaging quake to occur in California since the Long Beach earthquake of March 10, 1933. Its effects were noted north to Fresno, east to Las Vegas, and south to Mexico. The initial shock was registered by Cal Tech seismologists at 42 seconds after 6:00 a.m. with a magnitude of 6.6 (Richter) followed at 6:01 by a second shock of 5.4, then four other aftershocks close together. This series lasted five minutes, 11 seconds. During the period between 6:10 and 7:58 a.m., four after-shocks registering over 5.0 were recorded and in the first hour and 15 minutes there were 26 shocks between 4.0 and 5.0. Through February 23, 199 aftershocks of 3.0 or greater had been recorded.

Although the San Fernando earthquake's magnitude was only moderate, the severity of ground motion was close to the maximum generated by any earthquake - up to 75% of the earth's natural gravitational acceleration (0.75 g) according to the findings of a 12 man panel, headed by Dr. Clarence R. Allen of Cal Tech.

Los Angeles County Engineer John A. Lambie[3] stated that "the tremendous energy release in the locality (of Olive View Hospital) caused horizontal and vertical ground shaking exceeding the 6.5 earthquake." He further stated that "ground shaking equaled or exceeded an 8.0 earthquake at the point of maximum intensity."

George Housner, director of Cal Tech's earthquake engineering research, believes the acceleration force of the temblor at Olive View Hospital was 30 to 50% of the force of gravity. This would be the highest ever recorded throughout the world.[3]

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[3]Engineering News Record, February 25, 1971, P. 12

Readings at Century City in western Los Angeles were 0.17 g and in downtown Los Angeles, a force of 0.13 g was measured. State bridge engineers feel that the destruction of the bridges at the Route 5/210 Interchange required a lateral force in excess of 0.3 g. Such a force would greatly exceed the then existing lateral load design criteria.[4]

The accelerometer at Pacoima Dam, located about five miles south of the epicenter and about 3.5 miles east of Olive View Hospital, showed a maximum horizontal acceleration somewhat greater than that of gravity (1.05 g on the S16°E horizontal component).

It had been previously estimated that a magnitude 6.5 shock should produce an accleration of 0.1 g on "better ground", whereas a maximum of 0.3 g has been predicted for deep alluvium. The ground motions experienced during the San Fernando earthquake were therefore much more severe than would have been expected for shock of its magnitude.

D. Location

The epicenter of the quake was located by Cal Tech seismologists over the Soledad Canyon Fault (a minor rift some three miles in length) at its junction with the larger San Gabriel Fault. They further described the earthquake as taking place in the maze of faults that characterize the geologically unstable base of the San Gabriel Mountains.

Geographically, the epicenter is some 25-30 miles northwest of the Los Angeles Civic Center, or seven miles east of Newhall, as shown in Figure 1. With reference to damaged roads, the epicenter is located about eight miles northeast of the Route 5/210 Interchange and about two miles south of Route 14 near Soledad Canyon. Focal depth has been determined to be about seven miles. (See item E, Tectonic Movement).

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[4]California Division of Highways, "Roads to Recovery", submitted for publication in Highway Research News.

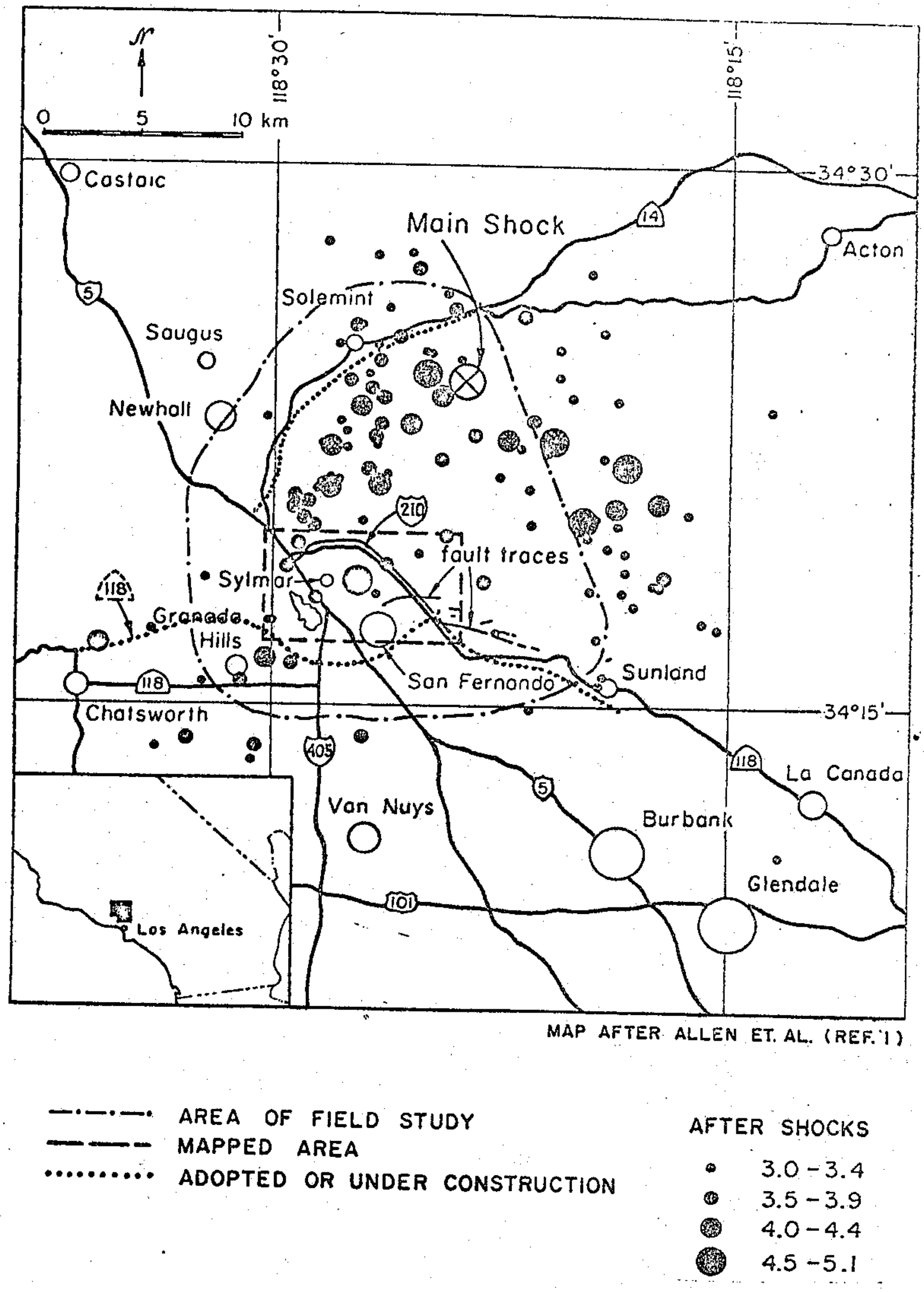


Figure 1 GENERAL AREA OF FIELD STUDY, MAPPED AREA, AND AFTERSHOCKS

The earthquake occurred in an area which had relatively low seismicity. Only one strong, destructive earthquake is known to have occurred previously in the San Fernando-Newhall area. This took place in 1893 about eight miles southwest of Newhall, registering about VIII-IX on the Modified Mercalli Scale.

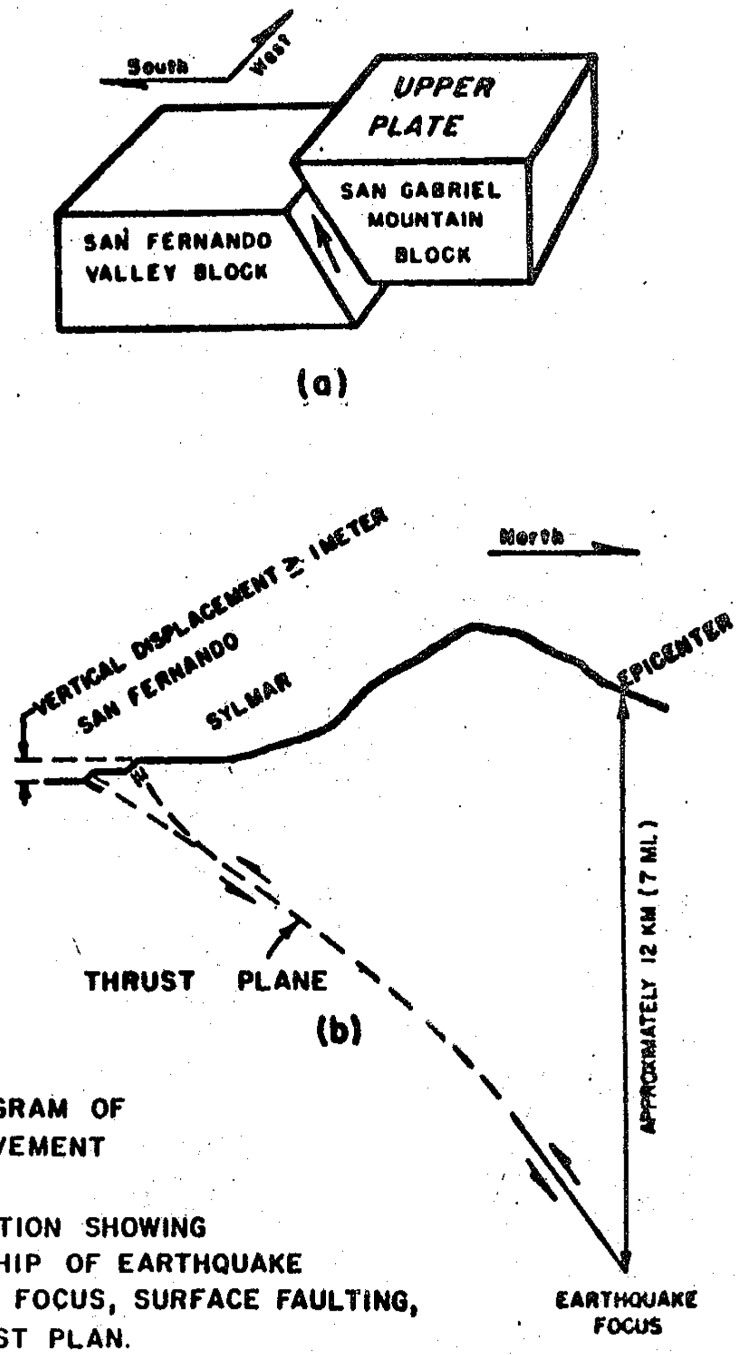
C. R. Allen of Cal Tech has reported that nothing in the recent seismic history of the Northern San Fernando Valley would indicate the area to be a more likely candidate than any other area for a 6.6 magnitude earthquake. Allen further points out, however, that the San Fernando earthquake was no great surprise since a quake of at least this magnitude occurs in Southern California on the average of about once every four years.

E. Tectonic Movement

Regional tectonic movement consisted of an upper plate (Figure 2a), more or less delineated by the inverted "U" shape formed by the aftershock locations shown in Figure 1, that moved to the south and west along a thrust fault plane dipping about 45° to the north. This upper plate moved over the lower plate as rupture progressed along the thrust plane from the hypocenter to intercept ground surface in the Sylmar-San Fernando area. Because of the shallow fault depths and large ground displacements, this was the area in which damage to engineering works was concentrated.

Continuing studies of the aftershocks by Cal Tech seismologists are contributing to the overall picture of tectonic movement. These shocks, with an average focal depth of about four miles (maximum eight miles), have been divided into the eastern group, the epicentral group, and the Chatsworth group. According to Hanks, et al,[1] the focal depths of the eastern group are fairly shallow and are

[1]Hanks, et al, "Precise Locations of Aftershocks of the San Fernando Earthquake", p. 21 of USGS-NOAA Report (See VI, Ref. #1)



(a) BLOCK DIAGRAM OF FAULT MOVEMENT

(b) CROSS-SECTION SHOWING RELATIONSHIP OF EARTHQUAKE EPICENTER, FOCUS, SURFACE FAULTING, AND THRUST PLAN.

Figure 2 BLOCK DIAGRAM AND CROSS SECTION OF FAULTING
AFTER R. GREENSFELDER
SEE VI REFERENCE *2, p. 64

above the thrust plane as defined by the epicentral group. Depths of the Chatsworth group, on the other hand; are deeper than the thrust plane. Based partly on this information Whitcomb[2] has suggested a model to describe the overall movement.

F. Damage to Bridge Structures

1. Introduction

Extensive damage to highway structures occurred during the San Fernando Earthquake of February 9, 1971 (see photos in Appendix III). On February 10, 1971, an investigation team consisting of four bridge designers and a geologist was assigned to the earthquake area to conduct an investigation of the damage to the highway structures. The purpose of the investigation was to assess the damage and to determine what can be done in design to improve the peformance of bridges in future earthquakes. The damage inspected was documented by photographs and sketches.

The major damage was confined to the area extending from Mission Hills on the south, northerly and easterly through San Fernando to the north junction of Routes 5 and 14. Damage to highway structures was recorded on Routes 5, 14, 210 and 405.

Damage to the highway structures varied from minor cracking and spalling to total destruction of several bridges. Most of the major damage occurred within the limits of two contracts under construction; the Route 5/210 Interchange (Guy F. Atkinson Company) and the Route 5/14 (Kasler-Ball). The Route 5 (Truck Lane)/405 Separation, a completed structure, also suffered severe damage and was demolished.

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[2]Whitcomb, "Fault Plane Solutions of the San Fernando Earthquake. . .and Aftershocks", p. 30 of USGS-NOAA Report (See VI, Ref. #1)

A total of six structures will have to be entirely replaced. They are: the San Fernando Road O.H., Bridge No. 53-730 R/L, San Fernando Road O.H., Bridge No. 53-1990 R, Route 210/5 Separation and O.H., Bridge No. 53-1989 L, Northwest Connector O.C., Bridge No. 53-1985, the Route 5 (Truck Lane)/405 Separation and the Los Angeles Aqueduct (Foothill Boulevard) Bridge No. 53C-316. At the Route 5/14 Interchange, two spans of a tall, long, and narrow ramp connector collapsed.

On Route 210 extending from its interchange with Route 5 to the Maclay Street U.C., structural damage is repairable. There was minor damage of wingwalls and slope paving, lateral displacement of an abutment, and minor spalling of columns.

An interesting phenomenon noted on this route was that the freeway which was on embankment settled uniformly. When sighting along this stretch of roadway, the profile was so uniform that some of the bridges appeared to have been pushed up by the earthquake. This settlement varies from 6 inches up to about 3 feet.

On Route 14 east of the Route 5/14 Interchange to the Santa Clara River, the damage consists of settlement of approaches and minor cracking and spalling of structures under construction.

2. <u>Geologic and Seismic Factors Affecting Bridge Damage</u>

Structural damage can be related to several geologic and seismic factors. The San Fernando Valley earthquake was a so called moderate earthquake. As was pointed out previously, the magnitude does not give an indication of ground response. Horizontal ground accelerations recorded near the Route 5/210 Interchange were on the order of 0.6 g (H. B. Seed, Panel Discussion March 16, 1971.)

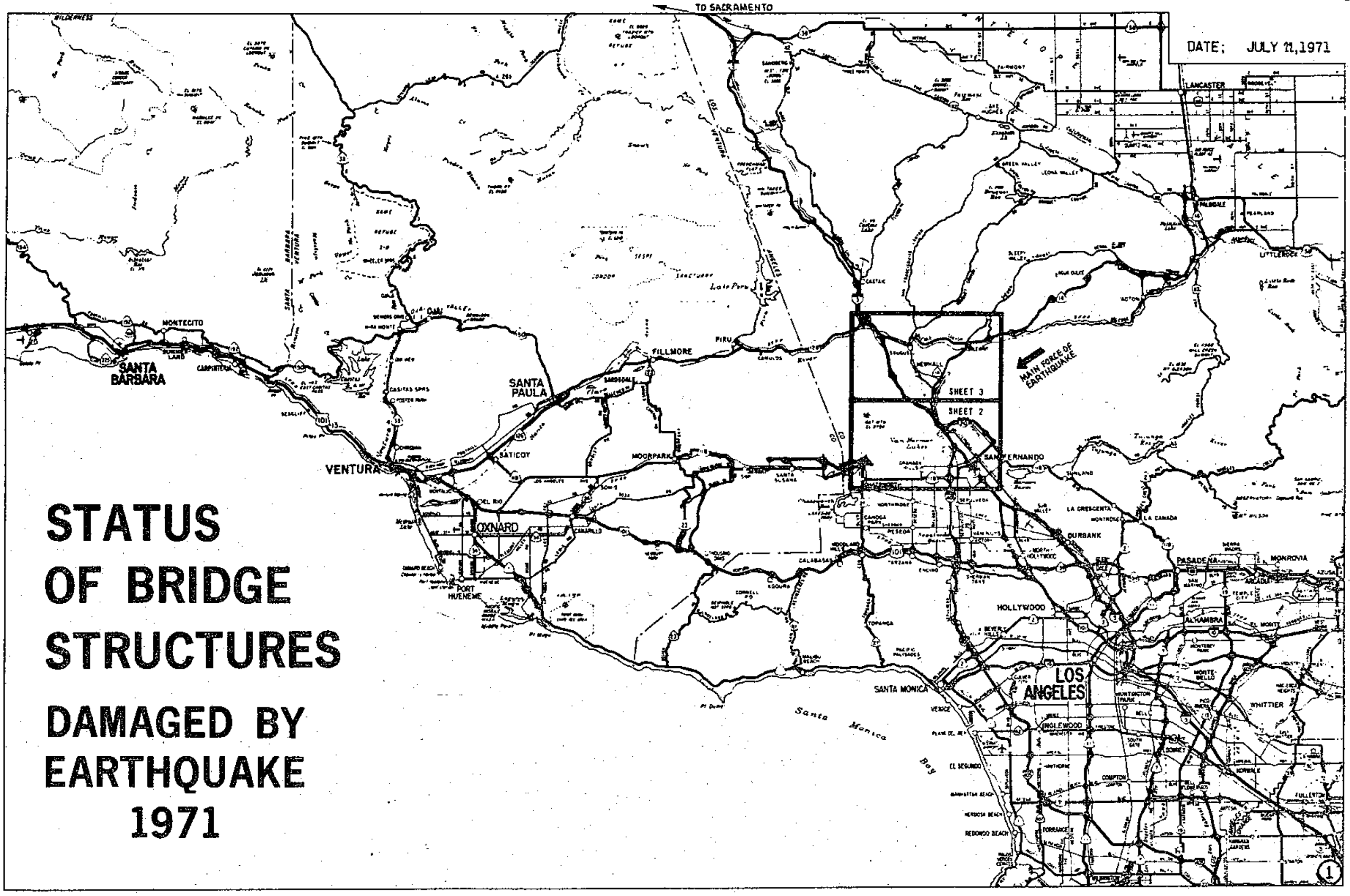
Surface geologic features and boring information give a good indication of subsurface conditions at the various structure locations. These conditions may be correlated with the degree of ground movement and the resulting structural movement. Structures located on unconsolidated material were subject to more severe ground movement than those located on consolidated or formation material. Actually the situation is quite complex because foundation type, depth and type of unconsolidated deposits, degree of consolidation, depth to ground water, and distance from the epicenter also must be taken into consideration. Ground movements caused distress in approach fills which in turn effected structural performance.

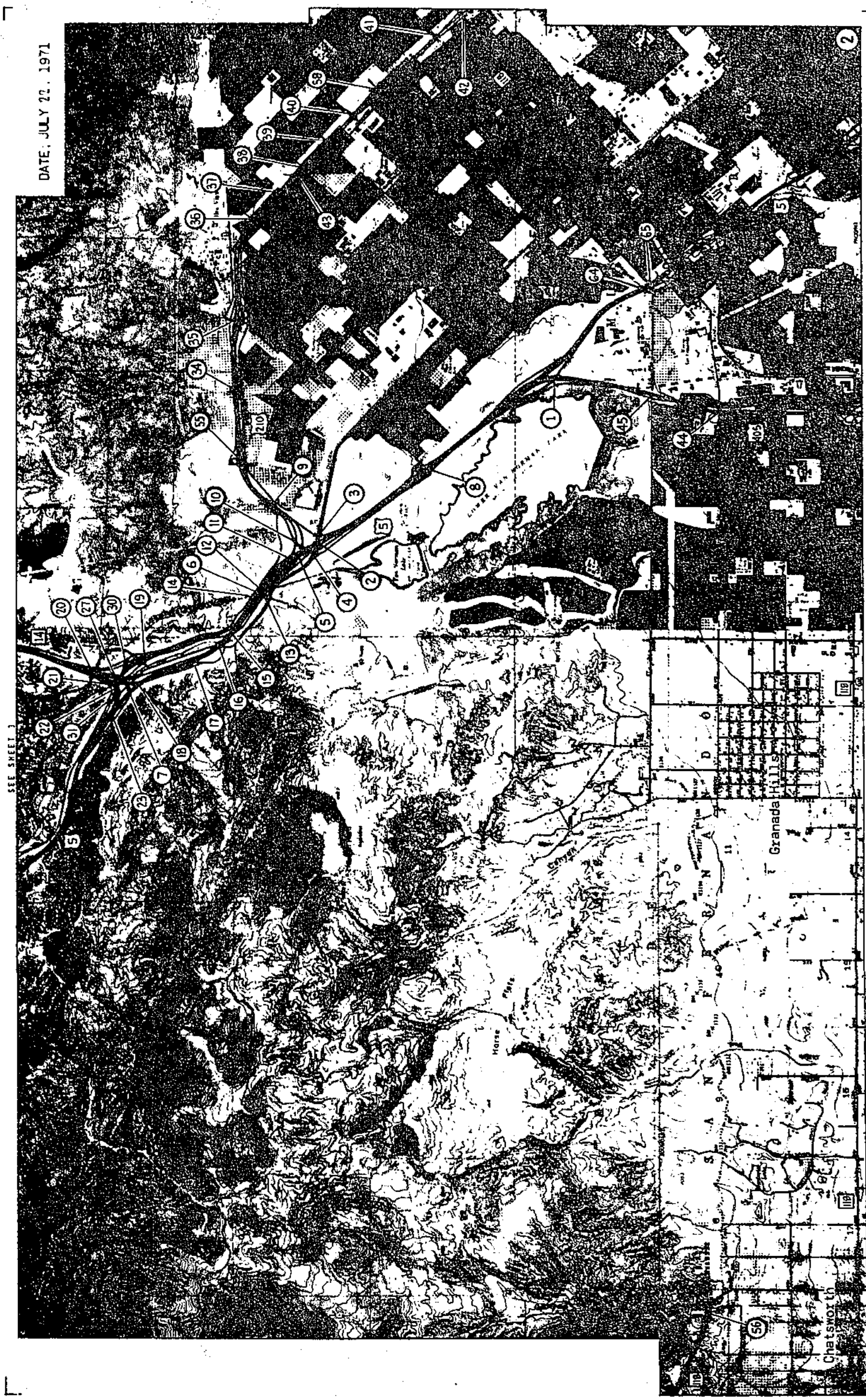
3. Approach Fills

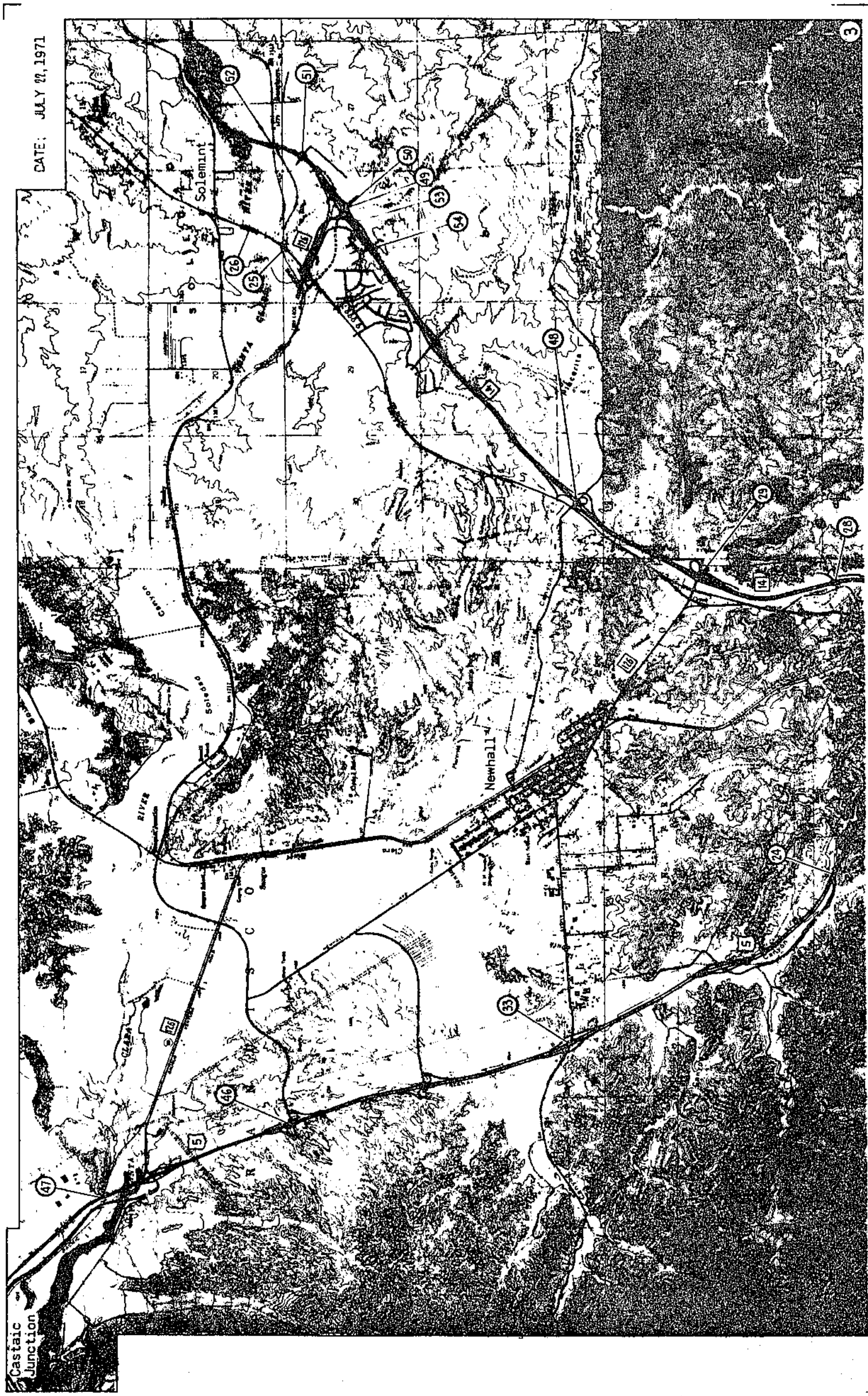
Abutment fills at many bridge sites showed considerable distress. Most of the fills involved settled while some were displaced horizontally. Major fill settlement in many abutment areas was in the backfill directly behind the abutment wall. Settlement of backfill in excess of three feet was noted at Roxford Avenue. The amount of fill settlement is related to the height and width of the fill, and the composition, of the embankment material. The relative density of granular basement soil, the elevation of the water table, and the existence of cohesive material also have a bearing on approach fill performance.

Following is a tabulation "Status of Bridge Structures Damaged in Earthquake", including a map of bridge locations.

Subsequent to the initial field investigation, the footings and columns below the ground were uncovered and examined for earthquake damage.


DATE; JULY 11,1971
STATUS
OF BRIDGE
STRUCTURES
DAMAGED BY
EARTHQUAKE
1971
TO SACRAMENTO
MAIN FORCE OF EARTHQUAKE
SHEET 3
SHEET 2
SANTA BARBARA
MONTECITO
CARPINTERIA
VENTURA
SANTA PAULA
FILLMORE
PIRU
MOORPARK
OXNARD
PORT HUENEME
SATICOY
SAN FERNANDO
BURBANK
HOLLYWOOD
LOS ANGELES
SANTA MONICA
PASADENA
MONROVIA
ALHAMBRA
WHITTIER
INGLEWOOD
COMPTON
FULLERTON
LANCASTER
PALMDALE
LITTLEROCK
CASTAIC
NEWHALL
LA CRESCENTA
LA CANADA
Santa Monica Bay
1


DATE, JULY 22, 1971
SEE SHEET 3
Granada Hills
Chatsworth
2


DATE: JULY 22,1971
Solemint
Newhall
Castaic
Junction
52
51
50
49
53
54
26
25
48
29
28
24
33
46
47
3
14
126
5

STATUS OF BRIDGE STRUCTURES DAMAGED IN EARTHQUAKE

DATE. JULY 22, 1971

INDEX NUMBER	BRIDGE	BRIDGE NAME	LOCATION	BRIDGE TYPE	DAMAGE	REQUIRED: EMERGENCY STRUCTURE	REQUIRED: EMERGENCY REPAIRS	REQUIRED: RESTORATION	COMPLETED: SITE RECONNAISSANCE	COMPLETED: EMERGENCY REPAIRS	COMPLETED: DESIGN EMERG. STRUCTURE	COMPLETED: NEGOTIATION OF EMERG. CONTR.	COMPLETED: EMERGENCY STRUCTURE	COMPLETED: PRELIM. INVEST. FOR RESTORATION	COMPLETED: P. S. AND E. FOR RESTORATION	CONTRACT AWARDED FOR RESTORATION	RESTORATION COMPLETED	REMARKS
1	53-1548	5/405 SEP S. BND TRUCK RAMP	07-LA-5, 405	(SPANS-TYPE-MAX SPAN) 2-CIP PS BOX 178 2 COLUMN BENT ON SPREAD FOOTING	TOTAL COLLAPSE REMOVE AND REPLACE	—	PART REM ✓	✓	—	PART REM ✓	—	—	—					EMERGENCY REMOVAL OF SPANS 1 & 2 - DAY LABOR $ 25 000 PENDING - REMOVE SUBSTRUCTURE - CONTRACT 25 000 PENDING - RECONSTRUCT - CONTRACT 300,000 4-71 ESTIMATED TOTAL $350 000
2	53-730 R/L	SAN FERNANDO RD OH (WIDENING)	07-LA-5 43.7	(SPANS-TYPE-MAX. SPAN) 7-RC BOX & PC PS "I" BEAMS MULTI COLUMN BENTS CLASS II PILES & SPREAD FOOTING	PARTIAL COLLAPSE MAJOR DAMAGE TO ENTIRE STRUCTURE REMOVE AND REPLACE ENTIRE STRUCTURE	✓	—	✓	✓	—	✓	✓	✓					2-71 EST. RESTORATION COST $2,000,000 (REMOVE EXISTING STRUCTURE $100,000, TEMPORARY DETOUR & REMOVAL $400,000, RECONST. $1,500,000)
3	53-1990 R	SAN FERNANDO RD OH	07-LA-210 0.0	(SPANS-TYPE-MAX. SPAN) 2-CIP PS BOX 122 SINGLE COLUMN BENTS 16" CIDH PILES	TOTAL COLLAPSE REMOVE AND REPLACE	—	—	✓	—	—	—	—	—					2-71 EST. RESTORATION COST $125,000
4	53-1989 L	RTE 210/5 SEP & OH	07-LA-5,210 0.0	(SPANS-TYPE-MAX SPAN) 7-RC BOX-129 CLASS II PILES & 6' DIA CIDH	TOTAL COLLAPSE REMOVE AND REPLACE	—	—	✓	—	—	—	—	—					2-71 EST. RESTORATION COST $350,000
5	53-1985	NW CONNECTOR OC	07-LA-5 43.8	(SPANS-TYPE-MAX. SPAN) MULTI COLUMN BENTS 6' DIA CIDH PILES	MAJOR DAMAGE TO SUBSTRUCT SUPERSTRUCTURE ROTATED NORTHERLY REMOVE AND REPLACE ENTIRE STRUCTURE	—	—	✓	—	—	—	—	—					2-71 EST RESTORATION COST $600,000 ENTIRE STRUCTURE REMOVED GENERAL PLAN DATED 6/21/71; EA #287831
6	53-1011	L.A. AQUEDUCT CHANNEL EXTENSION	07-LA-5 44.2	STRUTTED ABUTMENT AND RIGID FRAME 25' SPAN 70T AND 16" CIDH PILES	PARTIAL COLLAPSE (NORTHERLY 200' OF SUPERSTRUCTURE)	—	—	✓	—	—	—	—	—	✓				2-71 OVERBURDEN HAS BEEN REMOVED ABOVE COLLAPSED PORTION 4-71 REMOVE AND REPLACE DAMAGED PORTIONS ...$76,000 NEW DESIGN FOR DAMAGED PORTION REPAIR DETAILS SHEET, DATED 5/28/71 EA # 285841
7	53-1963	SO. CONNECTOR OC	07-LA-14 24.5	(SPANS-TYPE-MAX. SPAN, 9-RC BOX & CIP PS BOX SINGLE COLUMN BENTS 16" CIDH PILES & 10' DIA. PILES	PARTIAL COLLAPSE (SPANS 3 & 4 & PIER 4) HINGES 1 & 2 DAMAGED ABUTMENTS 1 & 14 DAMAGED	—	—	✓	✓	—	—	—	—					2-71 EST. RESTORATION COST $500,000 (LOSS OF FALSEWORK $100,000, RECONSTRUCTION $400,000)
8	53-1115	ROXFORD STREET UC (WIDENING)	07-LA-5 42.7	(SPANS-TYPE-MAX SPAN) 3-CIP PS BOX-85 PIER WALLS SPREAD FOOTING	RIGHT HALF STRUCTURE SHIFTED 10" NORTHERLY SPALLING AT DIAPHRAGM ABUT & PIER WALLS LEANING CURTAIN WALLS CRACKED	—	✓	✓	✓	✓	—	✓	—					7-71 RESTORATION COST 56,496 UNDER EMERGENCY CONTRACT #285824 7-71 EST. ADDITIONAL WORK (FUTURE) - $8,000
9	53-2016 R/L	FOOTHILL BLVD. UC	07-LA-210 0.6	(SPANS TYPE-MAX. SPAN) 4 - RC BOX-102 SPREAD FOOTING	COLUMNS BUCKLED & SPALLED ABUTMENTS SETTLED AND SPALLED	—	✓	✓		✓	—	✓	—					EMERGENCY CONSTRUCTION OF TEMP BENTS - EMER CONT $ 41,083 JACK WEST ABUTMENTS - DAY LABOR 25 000 PENDING - RESTORATION - CONTRACT 230 000 4-71 ESTIMATED TOTAL $296,083
10	53-1988 L	NO. CONNECTOR UC	07-LA-210 0.1	(SPANS-TYPE-MAX. SPAN) 3 - RC BOX-91 SINGLE COLUMN BENT SPREAD FOOTING	SPALLS IN TOP OF COLUMN ABUTMENT AND WINGWALLS CRACKED	—	—	✓	✓	—	—	—	—					2-71 EST. RESTORATION COST $ 20,000
11	53-1991 R	NBND TRUCK RTE. UC (CONNECTOR)	07-LA-5 43.9	(SPANS TYPE-MAX. SPAN) 3 - RC BOX-107 SPREAD FOOTING	EXTENSIVE DAMAGE TO ABUTMENTS AND COLUMNS	—	—	✓	✓	—	—	—	—					2-71 ESTIMATED RESTORATION COST $100 000 4-71 TEMPORARY SHORING IN PLACE AT BENTS 2 & 3 (BY CONTRACTOR)
12	53-1012	L.A. AQUEDUCT (PENSTOCK)	07-LA-5 44.2	STRUTTED ABUTMENT T BEAM & RC BOX CLASS I PILES	SPALLING AND CRACKING IN ABUTMENT WALLS	—	—	✓	✓	—	—	—	—	✓				4-71 REMOVE, REPAIR, REPLACE ABUTMENTS - $ $15,000 GENERAL PLAN DATED 7-2-71 EA #285841

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STATUS OF BRIDGE STRUCTURES DAMAGED IN EARTHQUAKE

DATE: JULY 22, 1971

INDEX NUMBER	BRIDGE	BRIDGE NAME	LOCATION	BRIDGE TYPE	DAMAGE	REQUIRED: EMERGENCY STRUCTURE	REQUIRED: EMERGENCY REPAIRS	REQUIRED: RESTORATION	COMPLETED: SITE RECONNAISSANCE	COMPLETED: EMERGENCY REPAIRS	COMPLETED: DESIGN EMERG. STRUCTURE	COMPLETED: NEGOTIATION OF EMERG. CONTR.	COMPLETED: EMERGENCY STRUCTURE	COMPLETED: PRELIM. INVEST. FOR RESTORATION	COMPLETED: P. S. AND E. FOR RESTORATION	CONTRACT AWARDED FOR RESTORATION	RESTORATION COMPLETED	REMARKS
13	53-1986	BALBOA BLVD. OC	07-LA-5 44.2	(SPANS-TYPE-MAX SPAN) 7-RC BOX 115 CLASS II PILES AND SPREAD FOOTING.	SHEARING AT ABUTMENTS. SPALLING & CRACKING @ HINGE DUE TO TRANSVERSE MOVEMENT	—	✓	✓	—	✓	—	—	—	✓				5-71 EST. RESTORATION COST $110,000 4-71 BENT 6 COLUMN REPAIRED TEMPORARY SHORING AT HINGE. EST $15.000 EA #285841
14	53C-316	L.A. AQUEDUCT (FOOTHILL BLVD)	07-LA CITY ST.	(SPANS-TYPE-MAX SPAN) 3-RC BOX-61 2 COLUMN BENTS ON STEEL PILES. ABUT ON SPREAD FTG	EXTENSIVE DAMAGE TO ABUTMENTS. COLUMN TOPS SPALLED AND CRACKED.	—	—	✓	—	—	—	—	—	✓				5-71 REMOVE AND REPLACE EST COST ...$210,000 - GP COMPLETE REDESIGN AS 2 SPAN STRUCTURE GENERAL PLAN DATED 6 21 71 EA #285841
15	53-1983	SBND TRUCK RTE. UC	07-LA-5 44.7	(SPANS TYPE MAX SPAN) 1 - RC BOX 66 STRUTTED ABUTMENT ON SPREAD FOOTING.	VISIBLE CRACKS AND SPALLS IN ABUTMENT WALLS. SEPARATION AT JOINTS IN DECK.	—	—	✓	✓	—	—	—	—	✓				2-71 EST. RESTORATION COST $50,000
16	53-1984 R/L	WEST SYLMAR OH	07-LA-5 44.6	(SPANS-TYPE-MAX SPAN) 4-RC BOX & CIP PS BOX MULT. COLUMN BENTS SPREAD FTG. AND STEEL PILES	SPALLING & CRACKING AT HINGE. HINGE RIGHT BR OPEN 3"- 5" PORTIONS OF ABUTS AND WINGWALLS DAMAGED.	—	—	✓	✓	—	—	—	—	✓				2-71 EST. RESTORATION COST $250,000
17	53-1965	SAN FERNANDO OFF-RAMP OC (CONNECTOR)	07-LA-5 45.0	(SPANS TYPE-MAX SPAN) 4 - RC BOX 134 SINGLE COLUMN BENTS STEEL PILES.	EXTENSIVE DAMAGE TO BOTH ABUTMENTS, BACKWALLS, AND WINGWALLS	—	—	✓	✓	—	—	—	—	✓				2-71 EST. RESTORATION COST $ 30,000
18	53-1960 L	RTE 14/5 SEP & OH	07-LA-5,14 24.5	(SPANS-TYPE-MAX SPAN) 10-RC & CIP PS BOX 178 SINGLE COLUMN BENTS 14' DIA PILES	* SEE REMARKS ABUT 1 CRACKED FALSEWORK SHIFTED IN SPANS 1 & 2 CAUSING CRACKING OF STEMS & SOFFIT.......etc....	—	✓	✓	✓	✓	—	—	—	✓				7-71 ESTIMATED RESTORATION COST $210,000 TO COMPLETE SPANS 9 & 10 AND 1,2 & 3. SPANS 9 & 10 POST-TENSIONED AFTER EARTHQUAKE EMERGENCY SHORING TO SPANS 9 & 10 COMPLETE .ETC *FALSEWORK SETTLED SPANS 9 & 10. MAJOR CRACKS BOTH SIDES PIER 6 CAPS. TOP OF PIER 5 DAMAGED BY 53-1961 EARLY CONTRACT PROPOSED FOR SPANS 1,2 & 3 CKD. DETAILS FOR SPANS 1,2 & 3 DATED 7 71. EA #287811
19	53-848 R/L	SIERRA HIGHWAY UC (RTE 5/14 SEP.)	07-LA-5 45.3	(SPANS-TYPE MAX SPAN) 3 - RC BOX 123	BOTH STRUCTURES SHIFTED OFF BEARING SEATS. EXTENSIVE DAMAGE TO PEDESTALS AND SHEAR KEYS. WINGWALLS DAMAGED	—	✓	✓	✓	✓	—	✓	—	✓	✓	✓	✓	7-71 RESTORATION COST $35,779.25 UNDER EA. #285834
20	53-1936 R/L/OR/OL	SIERRA HIGHWAY UC	07-LA-14 24.9	(SPANS-TYPE-MAX SPAN) 3 - RC BOX 104 MULTI COLUMN BENTS	DAMAGE TO WINGWALLS AT ALL ABUTMENTS	—	—	✓	✓	—	—	—	—	✓				2-71 EST. RESTORATION COST $ 50,000
21	53-849 OL	WELDON CANYON OH	07-LA-5 45.4	SPANS-TYPE MAX SPAN) 5 - RC BOX 77 SINGLE COLUMN BENT ON SPREAD FOOTING & 16"CIDH P!	DAMAGE TO BOTH ABUTMENTS SHEAR CRACKS IN EXTERIOR GIRDERS AT P-3. 3 HOLES THROUGH STRUCT. DUE TO FALLING BEAMS BARRIER RLNG DAM	—	—	✓	✓	—	—	—	—					2-71 EST. RESTORATION COST $ 50,000
22	53-1964	NO. CONNECTOR UC	07-LA-5 24.6	(SPANS-TYPE-MAX SPAN) 10-RC & CIP PS BOX-200 SINGLE COLUMN BENTS 16" CIDH PILES & SPREAD FOOTING	SPALLING AT HINGE 3 AND 4 REPLACE EQUALIZING BOLTS	—	—	✓	✓	—	—	—	—	✓				2-71 EST. RESTORATION COST $ 20,000
23	53-1959	TRUCK ROUTE UC	07-LA-5 45.7	(SPANS-TYPE-MAX SPAN) 1-RC BOX-41 & V STRUTTED ABUT ON SPREAD FOOTINGS & CLASS II PILES	SPALLING & CRACKING IN WALLS AT PORTAL JOINT. SEPARATION & OFFSET AT TRANSVERSE JOINT NEAR CNTR	—	—	✓	✓	—	—	—	—	✓				2-71 EST. RESTORATION COST $ 30,000
24	53-1797 R/L	GAVIN CANYON UC	07-LA-5 47.8	(SPANS-TYPE-MAX SPANS) 5-RC & CIP/PS BOX 208 2 COLUMN BENTS ON SPREAD FOOTING	SUPERSTR SHIFTED TRANSVERSLY 1 1/2". LOCALIZED SPALLING & CRACKING AT EACH HINGE RLNG DAMAGED	—	—	✓	✓	—	—	—	—	—				NO WORK STARTED - PLANNED BY DAY LABOR $ 8,000 ADDITIONAL IF HINGE REPAIRS REQUIRED. 22,000 4-71 ESTIMATED TOTAL $ 30,000

(5)

STATUS OF BRIDGE STRUCTURES DAMAGED IN EARTHQUAKE

DATE: JULY 22,1971

INDEX NUMBER	BRIDGE	BRIDGE NAME	LOCATION	BRIDGE TYPE	DAMAGE	REQUIRED: EMERGENCY STRUCTURE	REQUIRED: EMERGENCY REPAIRS	REQUIRED: RESTORATION	COMPLETED: SITE RECONNAISSANCE	COMPLETED: EMERGENCY REPAIRS	COMPLETED: DESIGN EMERG. STRUCTURE	COMPLETED: NEGOTIATION OF EMERG. CONTR.	COMPLETED: EMERGENCY STRUCTURE	COMPLETED: PRELIM. INVEST. FOR RESTORATION	COMPLETED: P. S. AND E. FOR RESTORATION	CONTRACT AWARDED FOR RESTORATION	RESTORATION COMPLETED	REMARKS
25	53-422 R/L	SOLAMINT OH	07-LA-14 30.87	(SPANS-TYPE-MAX SPAN) 3-RC T BEAM-56 SPREAD FOOTING AND STEEL PILES	TRANSVERSE MOVEMENT AT HINGE. MINOR SPALLS, TIE BEAM (BENT 3) FRACTURED. SW & RAIL DAMAGE.	—	—	✓	✓	—	—	—	—	—				4-71 EST. RESTORATION COST $2,000. PLANNED BY DAY LABOR. NO WORK STARTED.
26	53-423 R/L	SANTA CLARA RIV	07-LA-14 31.13	(SPANS-TYPE-MAX SPAN) 8-RC T BEAM-50 PIER WALLS ON STEEL PILING	MINOR DAMAGE (CRACKING AND SPALLING) TO ABUT 1 APPROACHS SETTLED	—	—	✓	✓	—	—	—	—	—				4-71 EST. RESTORATION COST LESS THAN $1,000 PLANNED BY DAY LABOR.
27	53-1960 R	RTE 14/5 SEP & OH	07-LA-5,14 24.5	(SPANS-TYPE-MAX SPAN) 8-RC BOX CIP PS BOX-194 SINGLE COLUMN BENTS 16" CIDH PILES & 10' DIA PILES	MODERATE DAMAGE ABUTMENT 1 HINGE 2 OPENED FALSEWORK SPAN 6 DESTROYED BY 53-1963	—	✓	✓	✓	✓	—	—	—	✓				4-71 EST RESTORATION COST $240,000 PORTION OF FALSEWORK STRENGTHENED. CHECKED DETAILS DATED 7.71 EARLY CONTRACT PROPOSED EA #287811
28	53-2096 R/L	LOS PINETOS UC	07-LA-14 25.4	(SPANS-TYPE-MAX SPAN) 4-CIP PS-138 16" CIDH PILES	MINOR SPALLING : ABUTS	—	—	✓	✓	—	—	—	—	✓				2-71 EST RESTORATION COST $ 3,000
29	53-2070 R,L & QR	14/126 SEPARATION	07-LA-14 26.5	(SPANS-TYPE-MAX SPAN) 1-CIP PS BOX-152 70 TON PILES	VISIBLE SPALLING AT ALL ABUTMENTS	—	—	✓	✓	—	—	—	—	✓				2-71 EST RESTORATION COST $ 1,000
30	53/1961	SIERRA HWY ON-RAMP UC (TRUCK CONN)	07-LA-5 45.4	(SPANS-TYPE-MAX SPAN) 3-RC BOX-162 2 COLUMN BENT ON SPREAD FTG	MINOR DAMAGE AT ABUTMENTS	—	—	✓	✓	—	—	—	—	✓				2-71 EST RESTORATION COST $ 1,000
31	53-996	WELDON UC	07-LA-5 45.7	(SPANS-TYPE-MAX SPAN) 4-RC BOX 126 SINGLE COLUMN BENTS ON SPREAD FTG & CLASS 11 PILES	MINOR SPALLING AT HINGE	—	—	✓	✓	—	—	—	—	✓				2-71 EST RESTORATION COST $ 1,000
32	53-1796	WELDON CANYON OC	07-LA-5	(SPANS TYPE MAX SPAN) 2-RC BOX 110 RC SINGLE COLUMN BENT RC STRUTTED ABUTS SPREAD FOOTING	MINOR CRACKING AND SPALLING AT TOP OF COLUMNS	—	—	✓	✓	—	—	—	—	—				4-71 EST. RESTORATION COST LESS THAN $1,000
33	53-1783	PICO-LYONS OC	07-LA-5 50.2	(SPANS-TYPE-MAX SPAN) 2-STEEL GIRDER-160	BEARING SEATS SHIFTED KEEPERS SHEARED	—	—	✓	✓	—	—	—	—	—				4-71 EST. RESTORATION COST $5,000 PLANNED BY DAY LABOR NO WORK STARTED.
34	53-1951	GLENOAKS BLVD UC	07-LA-210 1.5	(SPANS-TYPE-MAX SPAN) 1-CIP PS BOX-132 ON PILES	MINOR DAMAGE TO WINGWALLS AND SLOPE PAVING	—	—	✓	✓	—	—	—	—	✓				4-71 EST. RESTORATION COST $5,000. PLANNED BY CONTRACT. NO WORK STARTED.
35	53-1924	ROXFORD STREET UC	07-LA-210 2.0	(SPANS TYPE MAX SPAN) 1-CIP PS BOX-151 OR CLASS 1 PILES	TRANSVERSE MOVEMENT (3') CAUSED 100' PILE FAILURE RECONSTRUCTION OF ABUTMENT NECESSARY	—	✓	✓	✓	✓	—	—	—	✓				4-71 CONSTRUCT EMERGENCY FOOTING - DAY LABOR $ 6,000 PENDING RESTORATION .... CONTRACT $200,000 ESTIMATED TOTAL $206,000
36	53-1926	BLEDSOE STREET UC	07-LA-210 2.8	(SPANS-TYPE-MAX SPAN) 2-RC BOX 107 ON SPREAD FOOTING	TOP OF BOTH COLUMNS AT CENTER BENT SPALLED. ABUT. SETTLED & SPALLED WINGWALL DAMAGED.	—	✓	✓	✓	✓	—	✓	—	✓				4-71 CONSTRUCT EMERGENCY BENTS EMER CONTRACT $15,000 JACK ABUTMENTS (PERM REPAIR) DAY LABOR 25,000 PENDING RESTORATION .... CONTRACT 25,000 ESTIMATED TOTAL $65,000

6

STATUS OF BRIDGE STRUCTURES DAMAGED IN EARTHQUAKE

DATE: JULY 22, 1971

INDEX NUMBER	BRIDGE	BRIDGE NAME	LOCATION	BRIDGE TYPE	DAMAGE	REQUIRED: EMERGENCY STRUCTURE	REQUIRED: EMERGENCY REPAIRS	REQUIRED: RESTORATION	COMPLETED: SITE RECONNAISSANCE	COMPLETED: EMERGENCY REPAIRS	COMPLETED: DESIGN EMERG. STRUCTURE	COMPLETED: NEGOTIATION OF EMERG. CONTR.	COMPLETED: EMERGENCY STRUCTURE	COMPLETED: PRELIM. INVEST. FOR RESTORATION	COMPLETED: P. S. AND E. FOR RESTORATION	CONTRACT AWARDED FOR RESTORATION	RESTORATION COMPLETED	REMARKS
37	53-1925	TYLER STREET PED OC	07-LA-210 3.0	RC CONTINUOUS SINGLE CELL BOX GIRDER ON SPREAD FTGS	LONG MOVEMENT JOINTS AT ABUTS OPENED 10" COL. SPALLED AT TOP AND OUT OF PLUMB	—	√	√	√	√	—	—	—	√				4-71 CONSTRUCT EMERGENCY BENTS DAY LABOR $ 7 000; PENDING - RESTORATION 25 000; ESTIMATED TOTAL $ 32 000
38	53-1895 R/L	POLK STREET UC	07-LA-210 2.3	(SPANS TYPE MAX SPAN) 1-CIP PS BOX 146 ON CLASS I PILES	SPALLING AND CRACKING AT WINGWALLS RAILING SLOPE PAVING	—	—	√	√	—	—	—	—	√				4-71 ESTIMATED RESTORATION COST $ 16 000 PLANNED BY CONTRACT NO WORK STARTED
39	53-1896	ASTORIA STREET PED OC	07-LA-210	RC CONTINUOUS SINGLE CELL BOX GIRDER ON SPREAD FTG	SAME AS 53 1925 (INDEX NUMBER 37)	—	√	√	√	√	—	—	—	√				4-71 CONSTRUCT EMERGENCY BENTS DAY LABOR $ 4 000; PENDING - RESTORATION 25 000; ESTIMATED TOTAL $ 29 000
40	53-1927	SAYRE STREET OC	07-LA-210	(SPANS TYPE MAX SPAN) 2-RC BOX-118 ON SPREAD FOOTING	WINGWALLS SETTLED	—	—	√	√	—	—	—	—	√				4-71 ESTIMATED RESTORATION COST $ 6.000 PLANNED BY CONTRACT NO WORK STARTED
41	53-1897	HARDING STREET PED OC	07-LA-210	(SPANS TYPE MAX SPAN) 2 - RC BOX 104 3 COL BENT OR SPREAD FTG	LONGIT MOVEMENT CAUSED DAMAGE TO ABUTMENTS MINOR DAMAGE AT COLUMNS	—	√	√	√	√	—	—	—	√				4-71 CONSTRUCT EMERGENCY BENT DAY LABOR $ 1.000; PENDING - RESTORATION 3.500; ESTIMATED TOTAL $ 4 500
42	53-1898 R/L	MCCLAY STREET SEP (210/118)	07-LA-210	(SPANS TYPE MAX SPAN) 1 CIP PS BOX-145 ON CLASS I PILES	DAMAGE AT ALL WINGWALLS AND ABUTMENT CORNERS	—	—	√	√	—	—	—	—	√				4-71 ESTIMATED RESTORATION COST $ 20.000 PLANNED BY CONTRACT NO WORK STARTED
43	53-408	WILSON CANYON CREEK	07-LA-210 3.23	RC SINGLE BOX CULVERT 24' WIDE 15' CLEAR	SPALLS AT SOUTH PORTAL	—	—	√	√	—	—	—	—	—				4-71 ESTIMATED RESTORATION COST UNDER $ 1 000
44	53-1507	SAN FERNANDO MISSION BLVD UC	07-LA-405 47.24	(SPAN TYPE MAX SPAN) 3 RC BOX 90 SIMULATED CLOSED ABUTMENT ON CLASS II PILES	MAJOR SPALLING & CRACKING ON BARRIER RAILING. ENDS OF ABUTMENTS. JOINTS AND THE T-BEAMS	—	—	√	√	—	—	—	—					4-71 ESTIMATED RESTORATION COST $ 2 000 PLANNED BY CONTRACT NO WORK STARTED
45	53-1506	RINALDI STREET UC	07-LA-405 47.75	(SPANS TYPE MAX SPAN) 3-RC BOX-106 SIMULATED CLOSED ABUTMENT ON CLASS II PILES	CRACKS IN DECK OVERHANGS & RAILING SPALLS IN THE ABUTMENTS. PIER WALLS T-BEAMS & CURTAIN WALLS	—	—	√	√	—	—	—	—					4-71 ESTIMATED RESTORATION COST $ 15.000 PLANNED BY CONTRACT NO WORK STARTED
46	53-1815	VALENCIA BLVD OC	07-LA-5 52.3	2 SPAN STEEL GIRDER	BEARING SEATS SHIFTED KEEPERS SHEARED	—	—	√	√	—	—	—	—	—				4-71 ESTIMATED RESTORATION COST $ 4.500 PLANNED BY DAY LABOR NO WORK STARTED
47	53-688 R/L	SANTA CLARA OH	07-LA-5 53.66	(SPANS TYPE MAX SPAN) 3-RC T 63 3 COLUMN BENTS ON PILES	MINOR SPALLING AT VARIOUS LOCATIONS	—	—	√		—	—	—	—	—				7-71 ESTIMATED RESTORATION COST UNDER $1.000
48	53-2076 R/L	PLACERITA CANYON RD. U.C.	07-LA-14 27.6	(SPANS TYPE MAX SPAN) 1-CIP PS BOX 147 SPREAD FOOTING	ABUTMENT SHIFTED 3-8" ON FOOTING. MINOR SPALLING AND CRACKING ABUT I FACE	—	—	√	√	—	—	—	—	—	—	—		4-71 ESTIMATED RESTORATION COST $ 10.000 TO BE REPAIRED BY CONTRACTOR

⑦

STATUS OF BRIDGE STRUCTURES DAMAGED IN EARTHQUAKE

DATE: JULY 22, 1971

INDEX NUMBER	BRIDGE	BRIDGE NAME	LOCATION	BRIDGE TYPE	DAMAGE	REQUIRED: EMERGENCY STRUCTURE	REQUIRED: EMERGENCY REPAIRS	REQUIRED: RESTORATION	COMPLETED: SITE RECONNAISSANCE	COMPLETED: EMERGENCY REPAIRS	COMPLETED: DESIGN EMERG. STRUCTURE	COMPLETED: NEGOTIATION OF EMERG. CONTR.	COMPLETED: EMERGENCY STRUCTURE	COMPLETED: PRELIM. INVEST. FOR RESTORATION	COMPLETED: P. S. AND E. FOR RESTORATION	CONTRACT AWARDED FOR RESTORATION	RESTORATION COMPLETED	REMARKS
49	53-2166 R	VIA PRINCESSA UC	LA-14/126 30.4	(SPAN-TYPE-MAX SPAN) 1-CIP PS BOX-156 SPREAD FOOTING	6" 18" SETTLEMENT AT APPROACHES HORIZONTAL SHEAR FAILURE AT ABUT 2. CRACKING ABUT. 1 SPALLING AT SOFFIT LATERAL DISPLACEMENT	—		√			—		—	√	—	—		2-71 ESTIMATED RESTORATION COST $ 25 000 4-71 TEMPORARY SHORING AT BOTH ABUTMENTS TO BE REPAIRED BY CONTRACTOR
50	53-2166 L	VIA PRINCESSA UC	LA-14/126 30.4	(SPAN-TYPE MAX SPAN) 1-CIP-PS 161 SPREAD FOOTING	SEVERE SHEAR FAILURE AND SETTLEMENT AT ABUT. 2 3" CRACK VISIBLE GENERAL SPALLING & 3 1 2" CRACK IN SHEAR BLOCK AT ABUTMENT 1	—		√			—		—	√	—	—		2-71 ESTIMATED RESTORATION COST $ 25,000 4-71 TEMPORARY SHORING AT BOTH ABUTMENTS TO BE REPAIRED BY CONTRACTOR
51	53-2167	INDUSTRIAL ACCESS ROAD UC	LA-14/126 30.8	(SPAN-TYPE MAX SPAN) 1-CIP PS BOX-131 SPREAD FOOTING	MINOR SPALLING AT ABUT. 2	—	—	√		—	—	—	—	√	—	—		2-71 EST RESTORATION COST $ 5,000 TO BE REPAIRED BY CONTRACTOR
52	53-2027 R/L	SANTA CLARA RIV BR	LA-14/126 32.0	(SPAN-TYPE-MAX SPAN) 10-RC BOX-95 3 COLUMN BENT ON CLASS 1 PILES	DECK AT BOTH BRIDGES SPALLED AT HINGES EXPOSING RE-BAR LONGITUDINAL MOVEMENT 3 4" TRANSVERSE MOVEMENT 2". CRACKING A 1	—	—	√		—	—	—	—	√	—	—		2-71 EST RESTORATION COST $20,000 TO BE REPAIRED BY CONTRACTOR
53	53-2200	126/14 SEPARATION	LA-14/126	(SPAN-TYPE-MAX SPAN) 12 RC & CIP PS BOX 133	VERTICAL CRACKS IN EXTERIOR GIRDERS AT BENTS 10 & 11 3" LATERAL MOVEMENT OF ABUT 1 RELATIVE TO FOOTING MINOR CRACKS AT BENT 2	—	—	√		—	—	—	—	√	—	—		2-71 EST RESTORATION COST $20,000 TO BE REPAIRED BY CONTRACTOR
54	53-2171	CEDAR VALLEY WAY OC	LA-14/126 30.0	(SPAN-TYPE MAX SPAN) 3-RS & CIP PS BOX-142 2 COLUMN BENT ON SPREAD FOOTING	N E BARRIER RAILING AND END POST DAMAGED	—	—	√		—	—	—	—	√	—	—		2-71 EST RESTORATION COST $ 1,000 TO BE REPAIRED BY CONTRACTOR
55	53-2017 R/L	YARNELL STREET UC	07-LA-210	(SPAN-TYPE-MAX SPAN) 1-CIP PS BOX 148 16" CIDH PILES	WINGWALLS AND SLOPE PAVING DAMAGED	—	—	√	√	—	—	—	—	√				4-71 ESTIMATED RESTORATION COST $ 2,500 PLANNED BY CONTRACT. NO WORK STARTED
56	53-2182	BROWNS CANYON	07-LA-118 2.68	(SPAN-TYPE-MAX SPAN) 4-CIP PS BOX-210 3 COLUMN BENTS ON SPREAD FOOTING	SPALLING IN FACE OF ABUT 1 SHEAR KEYS AND END BLOCKS CRACKED	—	—	√	√	—	—	—	—	√	√	—	√	5-71 ESTIMATED RESTORATION COST $ 4,000 REPAIRED BY CONTRACTOR AS DIRECTED BY THE ENGINEER
57	53-1133	RTE 5/405 SEP	07-LA-5 41.57	RC BOX GIRDER TUNNEL SECTION ON SPREAD FOOTING	1" SEPARATION AT WINGWALL AND ABUTMENT ABUTMENT WALL CRACKED	—	—	√	√	—	—	—	—					4-71 ESTIMATED RESTORATION COST $ 5,500 PLANNED BY CONTRACT, NO WORK STARTED.
58	53-1928	HUBBARD STREET OC	07-LA-210	(SPAN-TYPE-MAX SPAN) 2- RC BOX-104 RC COLUMNS SPREAD FOOTING	N ABUTMENT SETTLED 4"	—	—	√	√	—	—	—	—	√				2-71 ESTIMATED RESTORATION COST $ 20,000 4-71 PLANNED BY CONTRACT. NO WORK STARTED
59	—	RETAINING WALL 80	07-LA-5	TYPE 1 RETAINING WALL	SECTIONS OF WALL DAMAGED	—	—	√	√	—	—	—	—	√				2-71 EST RESTORATION COST $30,000
60	—	RETAINING WALL 1569	07-LA-5	TYPE 1 RETAINING WALL	CRACKS AND SPALLS VISIBLE	—	—	√	√	—	—	—	—	√				2-71 EST RESTORATION COST $ 5,000

E. Damage To Roadway Facilities

1. General

Major road damage, and certainly the more spectacular, is concentrated within an area of about 12 square miles and involves approximately 10 miles of freeway. The fact that road damage within this small area is much more severe than damage outside the area is attributed to the large concentration of energy released during tectonic movements. In localized areas, all principal elements of the roadway sustained damage as direct results of seismic shaking. Damage was reflected in the following forms:

1) Cut slope failures

2) Subsidence of fills and underlying materials

3) Shear failures in fills and foundations

4) Faulting, separation, and buckling of pavement slabs

5) Cracking, separation, and distortion of drainage structures

6) Collapse and serious structural damage to bridges

7) Settlement at bridge approaches

2. Cut Slopes

Several slides in cut slopes were caused by the quake. The larger slides occurred on construction projects but would have had minimal effect on the travelled way had the road been in service. One exception, shown as Figure 3, was a bedding plane failure left of Station 1640 on Route 5. This slide would have blocked Ramp "V" which is designed to connect southbound traffic from Route 14 with San Fernando Road. Moderate to large earth volumes were involved in the three larger slides. Smaller slides were much less spectacular and some involved movement so small they were not detected during an initial damage survey. These slides, however, have affected the travelled way by their upthrusting action on the pavement section causing diagonal and longitudinal cracks and portions of the pavement to raise noticeably.

The behavior of cut slopes was dependent on type of material. For example slopes in dense, stiff, brittle materials (silts and silty sands containing enough non-plastic fines to have undergone desiccation to the extent that a cemented appearance was evident) fractured and shattered badly over distances of 20 to 30 feet behind top of cut, and often in the face itself. Materials of moderate density and a slightly greater moisture content experienced far fewer cracks and no shattering. Often only one or two large cracks were found along the slope top. Slopes in loose materials cracked behind the slope (where surface desiccation had occurred) in a parallel pattern and the slope moved successively in small amounts at each crack toward the unsupported surface. Sloughing or slumping in the slope face also occurred in this type of material.

3. Embankments

The type of damage most often observed was subsidence due to vibratory densification of fill and foundation materials, both of which consist of non-plastic silty, gravelly sands except at isolated locations. Subsurface soils were densified not only under fills but in areas outside the confining influence of fill weight. Greater densification did occur under the fills, however, especially at locations where the materials were in a very loose state prior to the quake. Generally, densification of foundation materials resulted in much greater amounts of fill subsidence than densification of the fill itself because the deposits of alluvium affected by the ground vibrations were in a looser pre-quake condition than the fill and are substantially deeper at most locations than fill thickness.

FIGURE 3. LANDSLIDE IN WELDON CANYON

The contribution of subsurface soil densification to fill subsidence can easily be detected at locations where rigid inclusions in natural ground pass under the fills. Differential subsidence results and a ridge or high area in the roadway surface is created over the non-yielding inclusion. As the fill on either side of the rigid element subsides, shear cracks are formed in the fill slopes, beginning at the toes and extending up the slope face. In cases of small relative movement the cracks may extend only about half way up the slope, but as total subsidence increases the cracks continue to develop and extend across the roadway. They may or may not be reflected in the pavement section but can be observed in unpaved medians and shoulders. This type of differential subsidence occurred at the Polk Street/210 Interchange and on Route 5 just north of Rinaldi Street. At both locations, a reinforced concrete box drainage channel was crossed by fills about 25 feet in height.

Some spreading of fills near structures is associated with densification within the fill due to the tendency for movement toward unsupported surfaces. This type of spreading in the fill proper was minimal, fairly uniform, and confined for the most part to the ends of approach fills under bridges. Fill spreading caused by lateral movement in foundation soils during densification was observed at a few locations but was limited in amount due to the inherent high shear strength of foundation soils. This resulted in bulging in the lower half of fill slopes and formation of longitudinal tension cracks in the upper half as the fill subsided differentially in a plane normal to centerline. Enough lateral movement near the fill toe did occur at some locations to cause minor thrusting of inside curb and gutter sections of freeway ramps. Also, as the fills subsided, the lateral component of slope paving movement sheared and rotated the curbs along the surface streets under the freeway structures.

Slipouts varying in size and amount of movement occurred in fills at several locations. Maximum movement did not exceed what normally would be considered a small amount but was sufficient to cause differential vertical displacements at longitudinal joints in pavement slabs, diagonal cracks across the pavement at the flanks, and minimal thrusting near the toe. Larger movement was prevented by the high strength properties of fill and foundation materials. The larger slipouts experienced the greatest movement and were observed to have occurred in long fills, all of which were 20-30 feet high. The smaller slipouts often experienced very little movement and in some cases were difficult to detect. They usually occurred in fills crossing small ravines and developed because of differential response by fill and natural ground. Consequently, lateral limits of these slides generally followed the cut/fill contact.

Three fill slipouts caused by plastic type movements in fine grained compressible foundation soils occurred within one fairly small area on Route 5 just east of the Lower Van Norman Lake. These slipouts involved more vertical and lateral movement than those occurring in fills only. The portion of fill undergoing movement dropped a maximum of one to 1.5 feet. Lateral movement was somewhat less due to the rotational effect, but large cracks up the fill slope were formed at the flanks. These slipouts covered a larger portion of the roadway than those in fills only.

The effect of subsidence and associated cracking on fill stability is considered negligible because of the high quality of fill materials. However, large quantities of water entering the larger cracks may cause sliding and sloughing within slopes and shoulder areas. Slipouts within fills only do not present stability problems for the same reason. No additional slippage is expected at locations involving failure in foundation materials since no additional loading is anticipated and the soil strength will be improved to near pre-quake levels through consolidation.

The overall effect of fill subsidence is a loss in roadway profile at cut/fill contacts and bridges. In some cases, especially at bridges, this abrupt change in profile is large enough to prevent traffic use of the road. In other cases the bump at bridge approaches is accentuated but traffic can still use the facility. Reconstruction will therefore be concerned largely with adjustment of profile.

4. Juvenile Hall Slide

One large translational slide in natural ground was located and mapped in the general area of the Route 5/210 Interchange area. This slide, covering about 60 acres of relatively flat ground, wrecked the San Fernando Valley Juvenile Hall just east of the interchange, and displaced a 1000-foot section of Route 5 about 5 feet to the west. A concrete lined channel parallel to Route 5, between the roadway and the Sylmar Power Converter Station, absorbed the slide movement but was demolished. Near the middle of the slide mass several sand boils were discovered which, although of small to moderate size, indicates liquefaction occurred in at least a portion of the slide.

Field evidence indicates the slide continued to move at a slow but decreasing rate during the first few days after the quake and then ceased moving. Recent aftershocks have had no measurable effect on the slide mass and no additional movement of any consequence is expected. The slide is currently being studied in detail and three boreholes along its axis have been made to obtain undisturbed soil samples.

5. Pavement

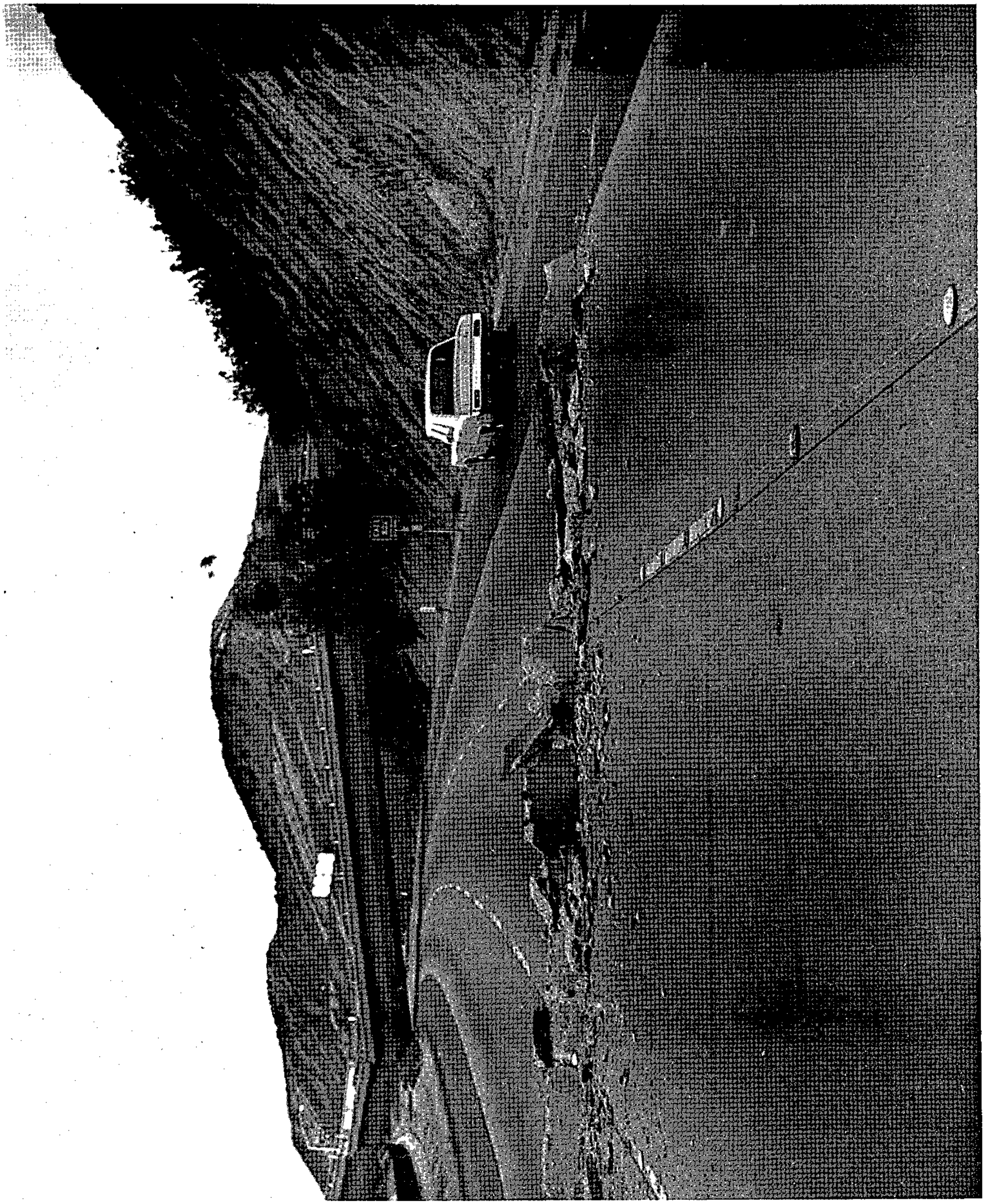
There is a surprisingly small area of damaged pavement considering the evidence of titanic forces exerted on the structures in the vicinity. There is no pattern to the type of damage that occurred. There are offsets where large areas of pavement moved horizontally, and there are other cases where the offset is the sum of approximate two-inch offsets occurring in a number of successive weakened plane joints. There are pressure ridges in the pavement with undamaged shoulders as shown Photo 1. Photo 2 shows a damaged shoulder alongside undamaged pavement. An unusual case is shown in Photo 3 where a pressure ridge in the pavement is adjacent to a shoulder that is pulled apart. Photo 4 shows damage to pavement and shoulder due to differential vertical movement.

The damage in Photo 5 appears to be a thrust fault type of movement with pavement on the right lapped over pavement to the left of the joint. The far lanes show vertical faulting in both transverse and longitudinal joints. In a few locations there is faulting in longitudinal joints without faulting in transverse joints and the reverse situation was noted.

Separation of a longitudinal joint is shown in Photo 6. There are no tie bars in this pavement, but similar separations occurred in older pavements with all of the tie bars broken at the joint. This confirms our 1965 State-wide survey which showed that minor differential settlement would break the tie bars.

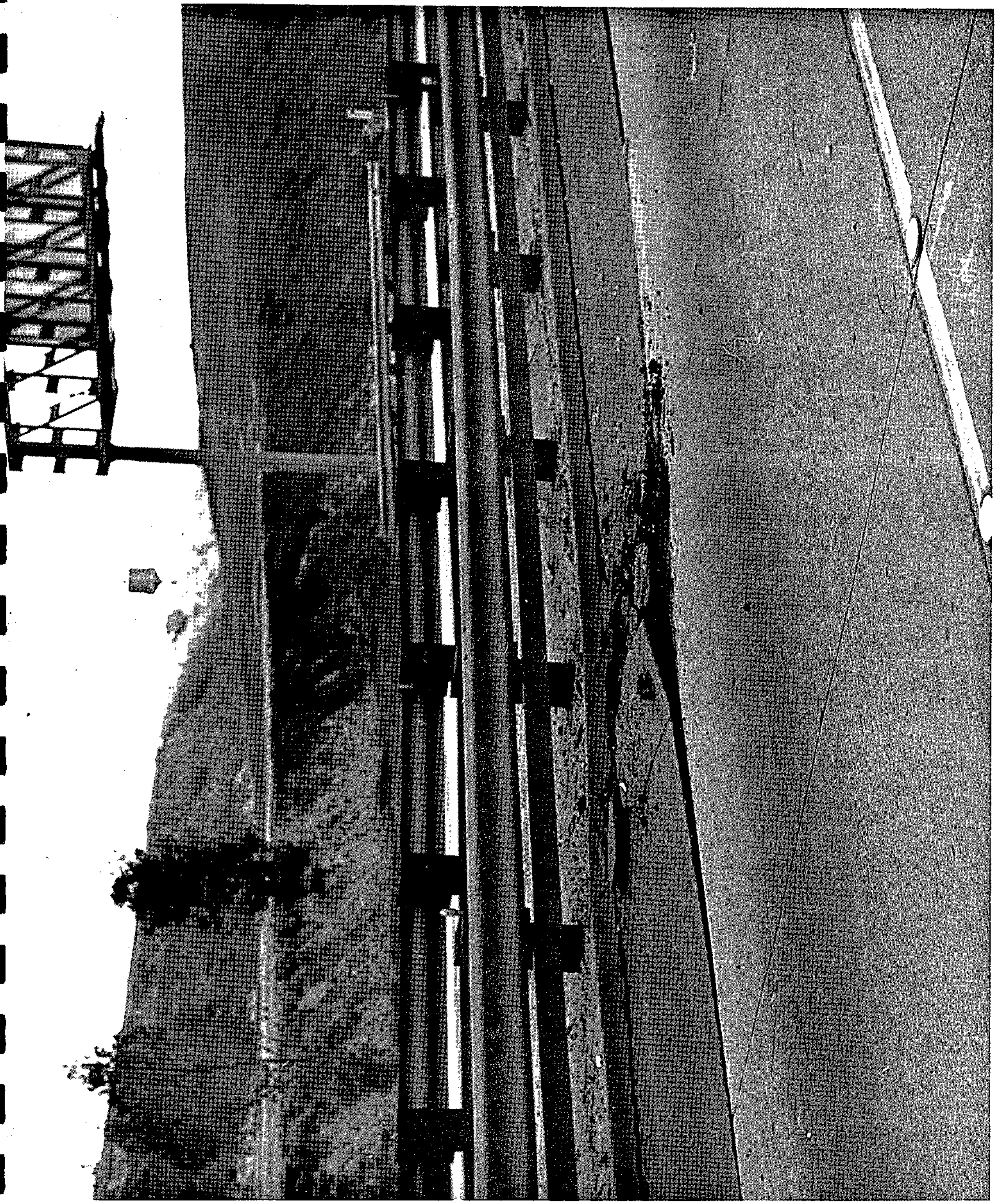
The damage to the existing Route 14 (Sierra Highway) was minor in nature and consisted of the settlement of the roadway embankment at various locations and slight damage to two bridge structures.

Only two locations on Route 14 roadbed experienced sufficient settlement to require repair work, namely the approaches to the Solamint Overhead Bridge No. 53-422 and the Santa Clara River Bridge No. 53-423. The damage to these two structures is discussed in other portions of this report. Additional settlement of a less serious nature occurred at several locations where the roadway passed from a cut to fill situation. This same situation was noted on several local roads in the area which were constructed on high embankments. The riding index of several miles of freeway has been determined in areas of undulating profile. Correction of profiles, especially at bridge approaches, will be done by mudjacking.



ON NB ROUTE 405 AT ROUTE 5

PHOTO 1



ON ROUTE 405 NEAR ROUTE 5

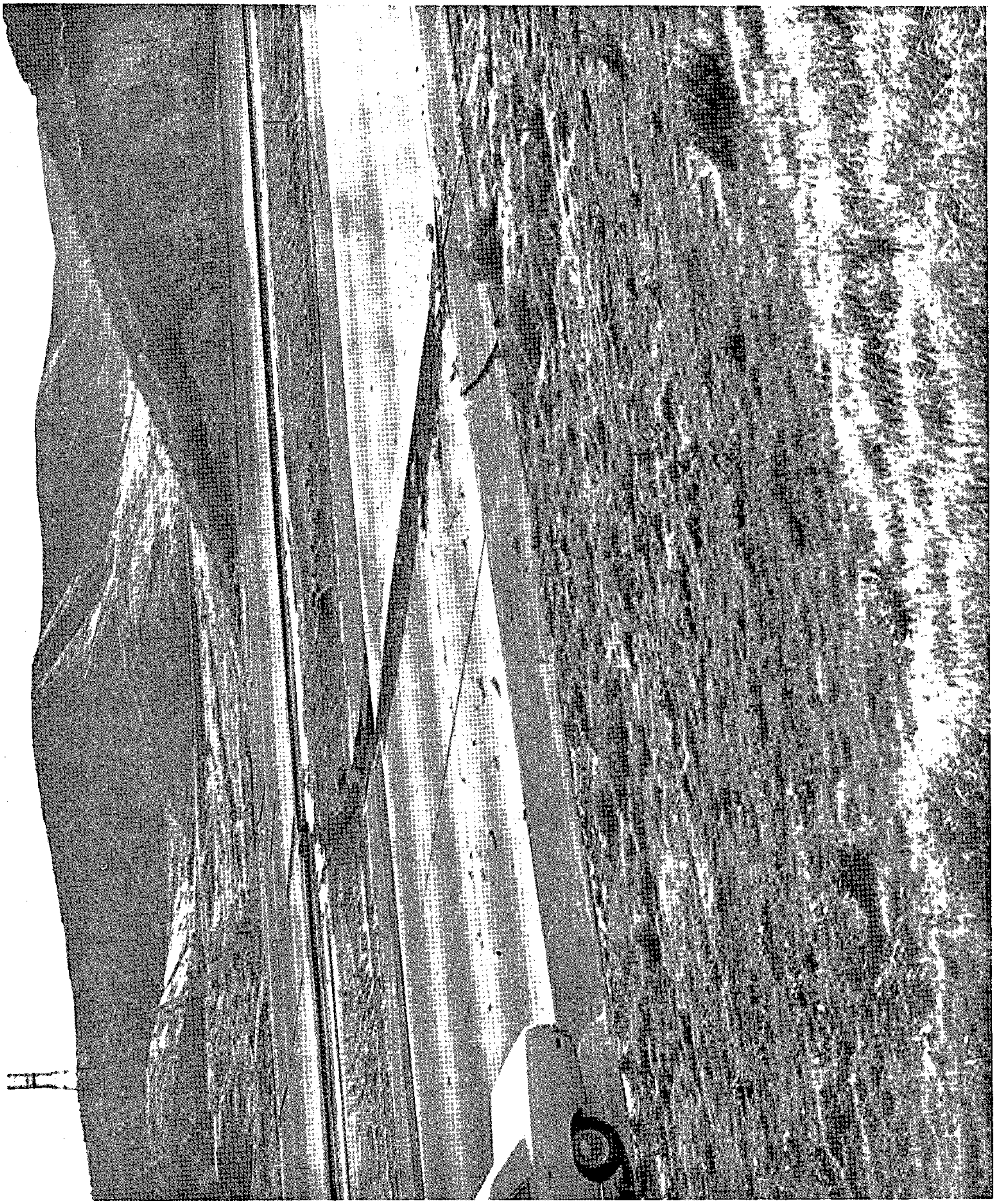
PHOTO 2

ON ROUTE 5 NEAR ROUTE 405

PHOTO 3

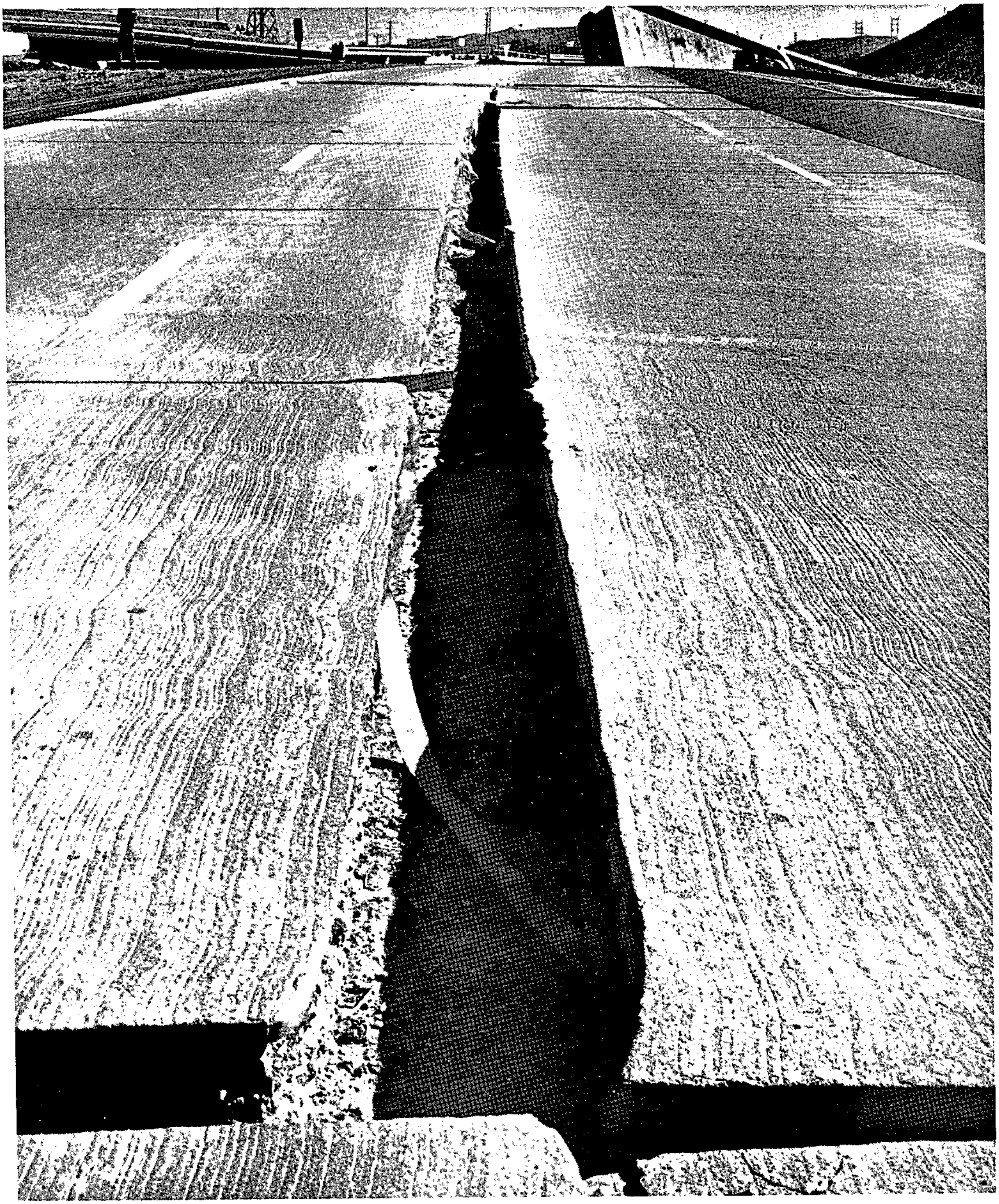
ON ROUTE 5 NEAR ROUTE 405

PHOTO 4



ON ROUTE 5 NEAR ROUTE 405

PHOTO 5



ON ROUTE 5 AT ROUTE 210

PHOTO 6

Damage to Foothill Boulevard consists of numerous cracks of varying width in the AC pavement, vertical displacement at AC pavement cracks, broken sections of curb, gutter, sidewalk and driveways, minor cracking and spalling of catch basins, and drastic upheaval of the pavement, curb, gutter and sidewalk at two locations. Some of the damage was caused by surface fault displacement, and some by failure of embankments or cut slopes. The latter damage may be due to vibrational effects of the earthquake shock waves or to readjustment of the earth's crust resulting from the pressure induced by surface faulting.

The most spectacular damage on Foothill Boulevard occurred at the intersection of Foothill Boulevard and Harding Street. Here the surface trace of the Sylmar Fault Segment crosses Foothill Boulevard. Slippage in this fault segment caused the pavement to heave upward several feet, presenting an irregular profile grade. Approximately 600 feet west of Paxton Street, the northerly curb line was uplifted approximately 3 feet, exposing a vertical scarp. This uplift was due to surface faulting on the Tujunga Fault Segment, but may have also experienced secondary effects from land slippage.

F. <u>Damage to Drainage Facilities</u>

Damage to drainage facilities resulted in joint separation for the most part. Repairs will consist of joint repair to prevent leakage of water and scouring or infiltration of water into the backfill material.

An exception to the above is a 39-inch RCP near the Olive View Hospital on Route 210 which suffered severe disjointing and offsetting to the extent that replacement of portions of this culvert may be necessary. Several vertical corrugated steel pipe risers from cross culverts to drop inlets were badly distorted, but only one to the extent that repair or replacement will be necessary. A box culvert paralleling Route 210 suffered considerable longitudinal cracking but it appears that this culvert can be repaired by grouting the cracks.

At the Route 5/210 Interchange area, an 87-inch reinforced concrete pipe located in a severe damage area has been fractured to the extent that the reinforcing steel is exposed (see below). Sections of this pipe may have to be replaced or reinforced with liner plate. Several of the drop inlets in the area were badly cracked and some have been tilted to the extent that the connecting pipes have been broken. Several of the drop inlets and connecting pipes may have to be replaced.

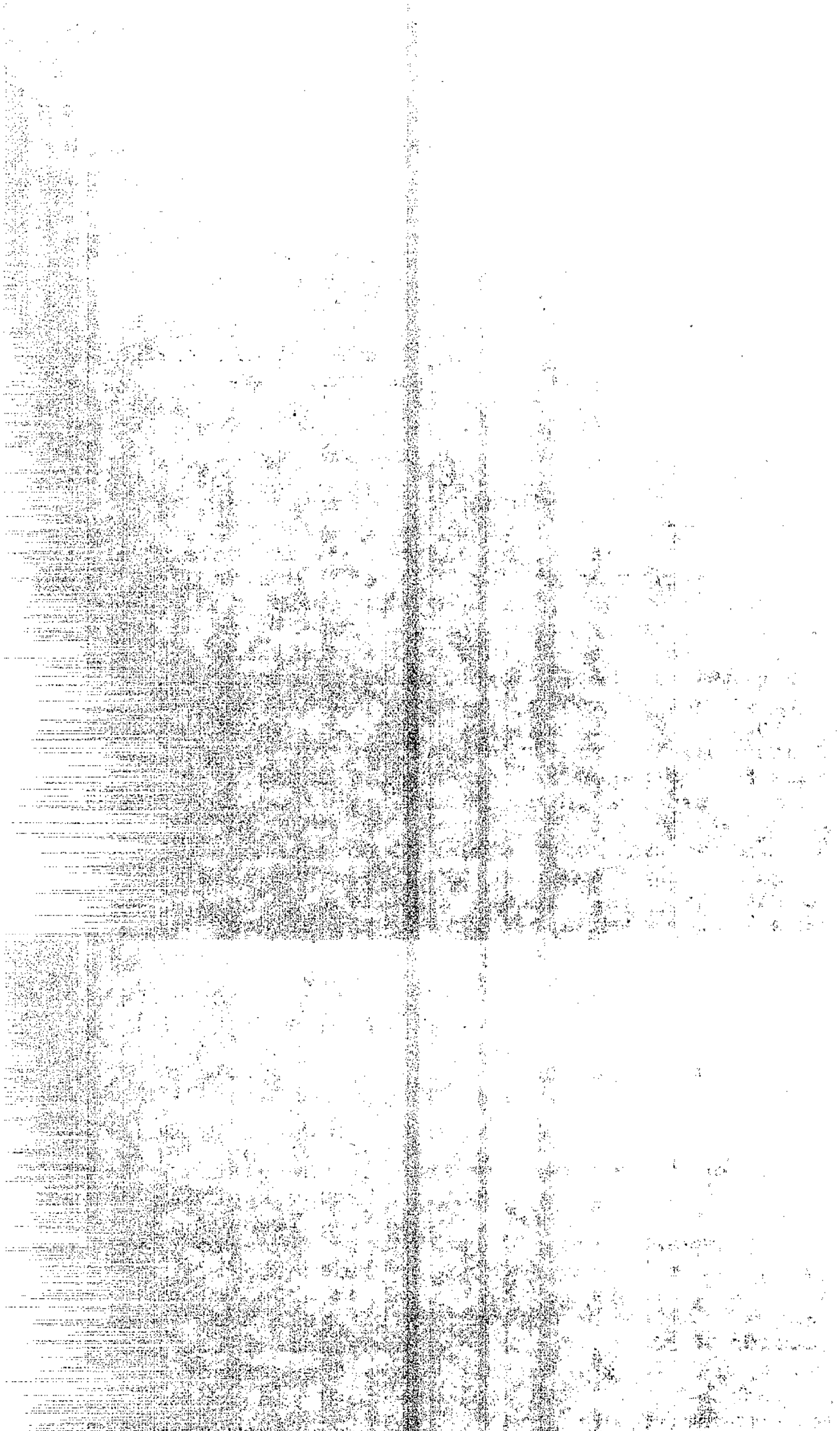
Inspection of major drainage structures in the earthquake affected area on Route 5, 405, 210 and 14 reveals considerable damage resulting in hair line cracks longitudinally and transversely or peripherally due to seismic effects and disturbance of soils. The distress in the embankments, due to severity of the earthquake disturbance caused excessive stresses on these structures and resulted in damages to RC pipes, RC Boxes and inlet structures. Immediate remedial measures have to be taken to prevent a hazardous situation and this will include pressure injection of epoxy adhesives into cracks in concrete prior to the 1971-72 winter season.

The major drainage structures have certain similarities being contiguous and located within the zone of damage. There are small longitudinal cracks going down the middle of the exterior walls and half way above the invert. There are 1/4" and 3/16" cracks at the top and bottom of the exterior and middle walls of RC Boxes where maximum negative moment exists. Similarly there is considerable hair line cracking in the pipe culverts. Most of the cracking is in the form of nearly horizontal cracking (continuous) about three or four feet above the invert. These cracks occur on both sides of the pipe. In addition, there are numerous transverse cracks extending above and below the longitudinal cracks. These transverse or peripheral cracks are predominant at almost every pipe joint.

In general, the damage to drainage facilities could be placed in two general categories. The first of these is the damage to large size RC Pipes. The 66", 72" and 87" pipes showed hair line cracking both longitudinally and peripherally. The magnitude and the size of the cracks in the 87" RCP, which was in the vicinity of the collapsed bridge, was great. A detailed inspection made by the Drainage, Design, and Bridge Departments revealed that a section of 208' length of 87" RCP was severely damaged, requiring a protective steel liner plate inside. This damaged portion had spalling with the rebar exposed, twisted and/or sheared. Cracks varying from 3/16" to 3/8" width with displacement as much as 1-1/2" to 2" was noticeable at the joints. The remaining portions of the 87" pipe could be repaired for cracks by injecting epoxy adhesive under pressure, and epoxy grout the transverse joints due to spalling of concrete. The other RC pipes were not severly damaged and are in repairable condition.

The other category is the RC Box structures located directly under the freeway fill or paralleling the freeway alignment. The inspection team's report and the Bridge Department review revealed that the RC Boxes had longitudinal cracks ranging up to 1/16" wide running about the middle of the end walls and the middle wall. There are 1/4" to 3/16" cracks at the top and bottom of the walls. Spalling with exposed rebar is noticeable at several of the joints.

Inspection of the 84" unreinforced, cast-in-place concrete pipe, located to the east of Route 5 and south of Roxford Avenue approximately 35' east of the toe of the freeway fill, revealed considerable damage due to the soil disturbance. Cracks as wide as 3/8" were noticeable in the 4 o'clock, 10 o'clock and 2 o'clock, 7 o'clock positions. The inside surface of the pipe appeared dislocated with 1/4" to 3/4" offset along these fractures. A length of 600' is badly damaged and appears no longer serviceable. At all other locations, the existing pipe may be salvaged by epoxy injection and spot patching.



CHAPTER II

COORDINATION WITH OTHERS AND INVESTIGATION

II. INVESTIGATION AND COORDINATION WITH OTHERS

The California Division of Highways is cooperating with the Earthquake Engineering Research Institute, which has contracted with the National Oceanic and Atmospheric Administration of the Department of Commerce, to perform a comprehensive study and prepare an in-depth report on this earthquake.

The Federal Office of Emergency Planning and the State Office of Emergency Services set up a disaster center in Los Angeles. Federal, State, and local agencies had representatives at that center and also in the disaster area where needed.

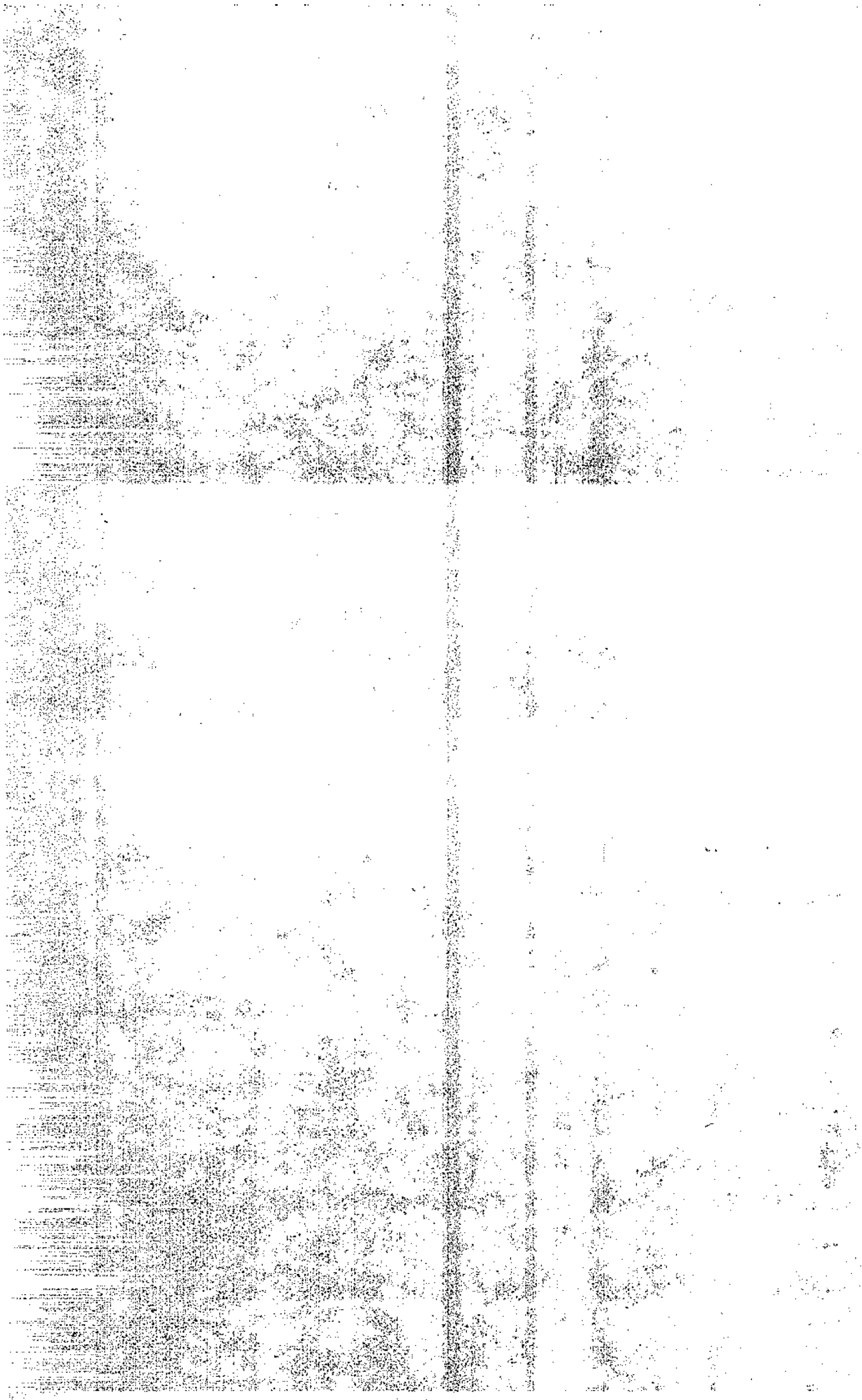
Teams of engineers from Federal Highway Administration, from the State Division of Highways and from the local agencies involved, reviewed damages to both State highway and street systems at the sites. All of these reviews were in accord with the 1970 Disaster Relief Act. Damage survey teams were fielded February 10, 1971 to identify and estimate the cost of the damage. (Public Law 606 for damages to other than Federally aided systems and Title 23, Section 125 for damages to systems involving Federal Funds originally). The Federal Highway Administration has advised that funds will be made available for restoration of damaged roads.

The reviews went very well and we believe that the teams have been reasonable in their determination of eligibility for permanent restoration.

Engineering surveys to establish relative horizontal and vertical movements of roadways were initated by District 7, Division of Highways to provide information for use by design personnel charged with the task of preparing plans for restoration of damaged sections. These surveys will be tied to precise control brought from outside the affected area through a cooperative effort with other agencies. National Ocean Survey section of the National Oceanic and Atmospheric Administration, and Los Angeles City and County, as well as other agencies, are cooperating with the survey effort.

CHAPTER III

TRAFFIC MANAGEMENT



III. TRAFFIC MANAGEMENT

A. Conditions Immediately Following Earthquake

Soon after the earthquake, reports of damage began to reach the Division of Highways' Communication Center. The first report of damage concerned slides on Route 2 and on Pacific Coast Highway. The reported slides on Pacific Coast Highway were false. Within the first hour District 7 had determined that:

1. The Golden State Freeway, the only direct north-south route from the San Joaquin Valley into the Los Angeles area was impassable in many locations.

2. Route 14 was closed due to the heavy damage suffered at the interchange between Routes 5 and 14.

3. The San Diego Freeway was impassable just south of the Golden State Freeway.

4. Route 210 Freeway east of Route 5 was closed.

5. Route 2, The Angeles Crest Highway, was closed by landslides approximately 5 miles north of Foothill Boulevard.

6. Telephone communications were out in most of these areas.

Approximately 11:00 a.m., evacuation of approximately 80,000 people below the Van Norman reservoir was ordered. This further complicated detour plans inasmuch as a likely alternate using Balboa Boulevard could no longer be considered. The Assistant District Engineer, Maintenance, was designated as general coordinator of repair and detour. By 12:00 noon a detour plan had been agreed to and work was underway by both State and contractors' forces. By 7:00 p.m., the day of the quake, one lane southbound Route 5 was opened and at 9:30 p.m., one lane northbound was opened for passenger vehicles and light trucks.

Work continued to improve this detour so that on February 11th at approximately 9:00 p.m., the Division was able to open two lanes, in each direction for Route 5 traffic excluding heavy trucks. By the same time one lane in each direction for Route 14 was operating over another routing on local roads and streets easterly of the damage area. Within 3 days after the quake, the Southern Pacific tracks were cleared and shortly thereafter trains resumed operation.

Due to continuous safety problems, the Division decided not to open the detour to all legal loads until February 19th. Meanwhile within two days after the quake the District had determined a general location for a 6 lane freeway detour immediately easterly of the former route. This detour would restore service to approximately the same standard as existed before the disaster with minimum interference to future reconstruction work. In a total of 10 days of design and 45 days of construction a $2,000,000 6-lane freeway approximately 2.5 miles long, mostly on new alignment (including a new bridge over San Fernando Road and the railroad) was placed in operation on April 15.

Several structures were reinforced with timbers to carry traffic - over, under and/or both. Several structures were removed to clear the railroad, freeway and conventional streets.

B. <u>Road Closure Actions and Subsequent Emergency Openings</u>

The emergency opening work consisted of constructing and signing to the detours, placing temporary patches in areas of broken or distorted pavements, shoring structures to prevent their collapse or to make them safe for public traffic, closing ramps and controlling traffic during the early stages of the emergency, and demolishing the various structures which had fallen across the traveled way and the Southern Pacific Railroad. Structures which were destroyed beyond repair and which have now been removed include the following:

1. Southbound truck Route 5 crossing Route 405.

2. Three crossings of the Southern Pacific Railroad and San Fernando Road in the Route 210/5 Interchange.

3. The northwest connector between Route 210 and Route 5.

4. Portions of the South Connector Overcrossing in the Route 5/14 intersection area.

The emergency opening work that was necessary to reopen satisfactory traffic service and to protect structures included the following:

1. Design, Construction and completion in two months of a six lane detour for Route 5 and 14 traffic between Roxford Street on the south and the Route 5/14 Intersection on the north. This included removing and relocating signs, lights, etc., grading and paving a detour and constructing a temporary six lane bridge in the vicinity of the San Fernando overcrossing; repairing the old Sierra Highway undercrossing of Route 14 and restoring surfacing throughout Route 5.

Overheight loads destined for the defense industries in the Palmdale area could not use this route in the early stages because of the restricted clearance at the Balboa Boulevard overcrossing. The normal Route for this traffic is via Balboa Boulevard and Foothill Boulevard. Because of this, it will be necessary to also provide temporary repairs to the Balboa Boulevard structure and to restore the Foothill Boulevard Bridge over the Los Angeles aqueduct as expediently as possible. This also involves work on the Los Angeles aqueduct structure located below the Foothill Boulevard bridge.

Repairs to the Roxford Street undercrossing on Route 5 were completed, and it was posted for restricted load limitations.

This detour was constructed with sufficient durability to carry State highway traffic for an anticipated two years.

The District also is preparing additional contract work to correct drainage and provide a surface suitable for high speed traffic on the portions of Route 5 and 405 south of Roxford Street and on Route 5 north of the Route 5/14 intersection.

The only traffic diversion that was in effect was the alternative of taking the detour on Route 126 to Ventura -- or "bearing with the problem" of delays through the devastated interchange of Routes 5/14/210.

C. Long-Term Traffic Handling Procedures

Once the geometrics of the detour were improved and the traffic handling capacity of the detour maximized, then the operation of the detour for maximum efficiency and safety was the prime concern.

Generally, traffic moved very well on the detours. However, congestion developed every Sunday afternoon on the southbound lanes of the Interstate #5 detour. Demand far exceeded the capacity. Delays of up to 45 minutes were experienced by as many as 14,000 motorists on a Sunday afternoon. Once the motorist was committed to the detour, there was no easy turn around or service stations available to him in the event of emergencies for approximately 10 miles.

To ease motorist frustrations during Sunday afternoon congestion, the District used innovative advance warning signs, roadside radio messages, "reassurance" signing and service patrol vehicles on the detour.

Advance warning signs were posted ahead of the congestion area warning of the impending tie-up and how long the delay would be. This permitted the motorist to stay in line or to get off the freeway if he so desired. Slowed traffic then moved into a roadside radio advisory zone where signs were posted suggesting motorists tune-in to 830 on their AM radio dial for a recorded message explaining the cause of the congestion, the estimated delay, and plans for correcting the situation.

Service patrol vehicles were on duty on the detours to provide emergency repairs, water and gasoline to the disabled motorist. Vehicles stalled in hazardous locations or in the traveled way were pushed to a safe area off the roadway, and traffic was kept moving. "Reassurance" signs on the detours were placed to let the motorist know that the end of this slow traffic was near.

The experience gained through long term traffic handling through the disaster area showed the value of operating the detour at maximum efficiency to move the traffic through with minimum delay and aggravation to the motorist.

Among the many technical innovations contributing to the speedy freeway recovery program, one of the most promising is the new "Los Angeles Area Freeway Surveillance and Control Project".

The project is an experimental effort to test and evaluate a freeway surveillance and control system that could eventually become a standard installation on most of our urban freeways. The project is multiphase and will include four basic phases: (1) an electronic surveillance system with traffic responsive ramp control; (2) early detection and rapid removal of unusual incidents; (3) "real time" warning and information; and (4) service for stranded motorists.

CHAPTER IV

RESTORATION OF HIGHWAY FACILITIES

IV. RESTORATION OF HIGHWAY FACILITIES

Restoration of the earthquake-damaged highways will be carried out largely in a series of contracts, with different considerations for the portion under construction at the time of the earthquake and the portions previously completed and under State jurisdiction. A minor amount of repairs are to be done by day labor.

A. Bridges

54 bridges are to be repaired, in addition to the 6 which require total reconstruction. The damage suffered by each bridge was described in Chapter I-F. Restoration of bridges will generally be done concurrent with roadway work, and will be carried out under a series of contracts, tabulated at the end of this Chapter.

B. Pavement

Pavement will generally be restored to the originally planned alignment and grade. Temporary patches constructed to carry emergency traffic, as well as several hundred feet of additional pavement marginally damaged, will be replaced with new concrete and asphalt pavement. Pavement slabs which were not cracked by the earthquake, but were left with an undulating profile, especially at bridge approaches, will be mudjacked into place.

C. Drainage Facilities

Restoration of damaged drainage facilities may be classified in four levels of repair:

1. Leave as is. Minor cracking is not expected to endanger the integrity of the facility or create a danger to life or property.

2. Apply grout. Cracks in pipes and box culverts are repairable by use of cement mortar or epoxy, applied by normal methods or under pressure.

3. Install liner inside the original pipe. This method is to be used where drainage conduit is too badly damaged for grouting. Another consideration may be that the conduit lies under a large fill, or under a heavily-travelled roadway, where excavation would be impractical.

4. Replacement. There are a very few cases in which drainage facilities which are broken or disjointed at the flow line will be dug out and totally replaced.

Early contracts are proposed under Method No. 2 to correct damage before the winter of 1971-72. The remaining drainage restoration will be accomplished under contract with the adjacent roadway and bridge work.

D. Earthwork

Restoration of freeway earthwork is proposed in two categories.

1. Slides in cut banks will be laid back to a stable slope, in line with normal practice. Approximately one-half million yards of excavation will be required for correction of earthquake-induced landslides. The slides on Route 5 near Van Norman Reservoir and in Weldon Canyon will be corrected as a part of the contracts to be let in those areas. The slides on Route 14 are being corrected as contract change orders on contract 035624.

2. Fills have slipped out and subsided in several locations along Routes 5 and 210. At four locations on Route 5, it will be necessary to excavate the outside 12' of the roadway prism and recompact the fill. In addition, a 4' depth below finished freeway grade will be excavated and recompacted at bridge approaches on Route 210, and in the vicinity of slipped-out fills on Route 5.

There are also some minor cracks and loosely compacted surface material on cut and fill slopes on Route 210. Recompaction will be accomplished by running a heavy bulldozer over the slopes.

E. Construction Program

The following tabulation lists the projects necessary to restore the damaged highways and to complete the work underway at the time of the earthquake.

Emergency projects were those carried out as force-account contracts during the first few weeks after the quake, for the purposes of restoring traffic service, investigating damage, and securing bridge work underway.

Restoration projects are planned to be carried out as soon as adequate investigations and plan preparation permit. Termination of existing contracts 068314 and 068324 are required for those jobs indicated.

Listed separately are projects which combine damage restoration with originally-planned construction work.

Negotiation for termination of the two original contracts (068314 and 068324) is underway under the provisions of Senate Bill 682 which provides the legal vehicle for termination.

F. Emergency Projects

	Location-Contract	Type of Work	Est. Cost (Not Incl Engrg Costs)
1.	LA-5 42.7/44.7 (068314: Atkinson) 288814	Phase I: 4-lane detour Completed February 9, 10, 11	$ 100,000
2.	LA-5 42.7/44.7 (068314: Atkinson) 285824	Phase II: 6-lane detour (Projects A and B) Completed April 15, 1971	$ 1,255,000

3.	LA-5 42.7/44.7 (068314: Atkinson) 285824 - 30001	Phase III: Bridge damage investigation Completed April 30, 1971	$ 12,400
4.	LA-5 44.7/46.2 (068324: Kasler-Ball) 285834	Phase I: 4-lane detour Completed February 9, 10, 11	$ 40,000
5.	LA-5 44.7/46.2 (068324: Kasler-Ball) 285834	Phase II: 6-lane detour (Project D) Completed April 15, 1971	$ 91,000
6.	LA-5 44.7/46.2 (068324: Kasler-Ball) 285834 - 30001	Phase III: Bridge damage investigation Completed May 28, 1971	$ 21,700
7.	LA-5 44.7/46.2 (068324: Kasler-Ball) 285834 - 30002	Connector "A" super bent Completed May 10, 1971	$ 102,600
8.	LA-5 44.7/46.2 (068324: Kasler-Ball) 285834 - 30003	Connector "C" Completed May 14, 1971	$ 16,700
		TOTAL	$ 1,639,400

G. Restoration Projects

	Co-Rte-PM-EA	Project Limits, Type of Work	Est. Cost (Not incl Engrg Costs)
1.	LA-5 40.5/42.6 287851	Rinaldi Street to Roxford Street Repair Culverts - pressure epoxy	$ 52,000
2.*	LA-5 42.6/45.6 LA-210 0.3 287861	Roxford Street to Route 14; 0.3 Mi East of Route 5 Repair culverts - pressure epoxy	$ 105,000
3.	LA-5 40.0/42.7 LA-405 47.2/48.6 287821	Rinaldi Street to Roxford Street San Fernando Mission Boulevard to Route 5 Repair Freeway pavement and structures	$ 1,600,000

4.*	LA-5 44.2 285841	At Los Angeles Aqueduct Reconstruct and repair Foothill Boulevard Bridge and Aqueduct structures	$ 272,800
5.*	LA-5 44.2 287871	At Balboa Boulevard O.C. Repair structure	$ 122,000
6.	LA-5 46.5/53.9 NEA 046	Weldon Canyon to Santa Clara River Repair bridges - minor damage	$ 150,000
7.	LA-5 47.2/47.5 288300	Weldon Canyon to Gavin Canyon Repair pavement	$ 100,000
8.	LA-14 30.8/31.1 NEA 049	Solamint, at Solamint OH, Santa Clara River Bridge (existing highway) Reconstruct approaches and repair bridges (to be done by highway and bridge maintenance departments)	$ 2,500
9.	LA-14 27.5/32.5 NEA 050 (CCO)	Placerita Canyon Road to Santa Clara River Slide removal and bridge repair	$ 65,000
10.	LA-210 0.5/4.9 286101	0.3 Mi North of Yarnell Street to Maclay Street Bridge repair and reconstruct freeway pavement, slopes and drainage	$ 2,200,000
11.	LA-210 R0.8/R1.4 286141	Foothill Boulevard at Yarnell Street and Glenoaks Boulevard Street restoration	$ 10,000
12.	LA-210 0.8/6.0 286131	Foothill Boulevard from Yarnell Street to Paxton Street Repair Roadway	$ 145,700
			$ 5,025,000

H. Combined Restoration and Freeway Completion

Co-Rte-PM-EA	Project Limits, Type of Work	Estimated Cost Restoration	Estimated Cost Completion
1.* LA-14 24.5 287811	At Route 14/5 Separation and OH Repair bridges (Conn. A and C) . . . . . . and complete portions . .	$ 210,000	 $ 300,000
2.* LA-5 42.7/44.7 LA-210 0.0/0.8 287831	Roxford St to W Sylmar OH Rte 5 to Yarnell St Repair freeway pavement and structures. . . . . . and complete contract 068314.	$ 4,900,000	 $ 2,100,[illegible]
3.* LA-5 44.7/46.2 LA-14 24.3/26.4 287841	W Sylmar OH to Weldon OC Rte 5 to San Fernando Rd Repair freeway pavement and structures. . . . . . and complete contract 068324.	$ 970,000	 $ 7,450,[illegible]
	TOTAL	$ 6,080,000	$ 9,850,[illegible]

Grand Total Restoration, including Emergency Work (Total F, G, H) (not including engineering costs) (not including contract termination) $ 12,744,400

*Within limits of contracts 068314 or 068324, termination of which is required before new contract award.

CHAPTER V

DESIGN OF FREEWAY ROADWAY AND STRUCTURES

V. DESIGN OF FREEWAY ROADWAY AND STRUCTURES

A. Bridge Structure Design

Design Criteria Prior to Quake

The criteria used by the Bridge Department in the design of structures for earthquake forces are based on "Recommended Lateral Force Requirements" developed over a period of years by the Seismic Committee of the Structural Engineers Association of California.

Evaulation of Design Criteria

A Task Force of designers from the Sacramento Office of the Division of Highways was assigned to survey and analyze the structure damage. Pictures were taken and sketches made of bridges that were destroyed or badly damaged.

Provision for Continuing Evaluation

A special Bridge Department Task Group has been created to provide for continuing long-range evaluation and modification of earthquake resistant design criteria.

The over-all goal is to consider and establish changes in design details, loading, and analysis to further increase structure resistance to seismic forces. Specific tasks assigned to this Task Group include:

1. Continue to gather factual information on the magnitude, frequency and direction of ground movements of the San Fernando earthquake.

2. Review and maintain a file of available literature on structural performance in past earthquakes, particularly information that relates to bridges.

3. Continue to review our current seismic design criteria for consistency with current or pending recommendations of the Structural Engineers Association.

4. Study the merits of relating criteria to zones of seismic probability.

5. Recommend rational assumptions that can be made in the application of loads to structural framing systems.

6. Adapt the dynamic capability of the STRUDL Computer Program to the seismic analysis of bridges.

One of the Division's Design Engineers has recently been asked to serve on the Seismic Committee of the Structural Engineers Association of California. This affords us an opportunity for continued close liaison with this committee.

The Federal Highway Administration has invited members of the Division of Highways to serve on an Advisory Committee in connection with a proposed 3-year FHWA Research Program. The purpose of this program is to develop recommendations in regard to seismic forces as related to the design of bridge structures. This research will involve the sophisticated earthquake testing facility at the Earthquake Engineering Research Center which was established in 1968 under the University of California.

In general, this research program will consist of two phases. The first will be to check world literature on the subject; the second phase will involve analytical and experimental study of bridge models of various configurations.

The function of the Advisory Committee will be to guide the work by staying in contact with the project during the three-year period.

The Division of Highways is also cooperating with the Earthquake Engineering Research Institute which has contracted with the National Oceanic and Atmospheric Administration of the Department of Commerce to perform a comprehensive investigation and prepare an in-depth report of the Los Angeles earthquake.

Recommendations

Interim Modification of Design Criteria

Improved bridge details thus developed are intended for use where applicable in the restoration of the damaged structures, in future bridge designs, on going contracts to the extent practicable, and to some extent in the modification of existing structures.

In regard to the evaluation of seismic factors and methods of analysis, it is being considered as an interim measure (until further research can be accomplished) to double the earthquake factor for bridges with spread footings and to increase by 2-1/2 times the earthquake force for bridges founded on piles.

Based on the field investigation and the conclusions, the following steps are being taken to improve the performance of structures subjected to earthquake loads.

1. Keep the number of hinges in the superstructure to a minimum. If hinges are used, ample seat sizes shall be provided and be adequately tied to resist horizontal and vertical seismic forces.

2. Hinges, preferably, shall be located such that there are at least two bents between the hinges in a frame.

3. Number of column ties will be increased at the points of high stress.

4. On single column bents, the use of lap splice for bar reinforcement at the base of columns will be discontinued.

5. Use of spirally reinforced columns or cores will be used.

6. To prevent the "punching" failure of caps over their columns during construction, more reinforcement will be placed in cap.

7. Use of a more positive seismic key at abutments to resist earthquake forces.

8. Eliminate the use of the rocker type bearings.

9. Where possible, reduce or eliminate the skew of structures.

10. Improve the design of skewed abutments to prevent the structure from rotating toward its acute corners.

11. The present earthquake design criteria and methods of analysis will be continually reviewed and modified to increase structure resistance to both horizontal and vertical seismic loads. The methods of dynamic analysis will be pursued.

B. Pavement and Drainage Structure Design

Design Criteria

Standard design criteria and normal construction methods were used. Structural design of the roadbed is concerned with the determination of the optimum combination of pavement and underlying layers for each set of project controls. The optimum design is the combination that is estimated to give the most economical service, normally for a 20-year period following construction.

Drainage structure design is based on storm runoff requirements as well as bedding and backfill conditions. Technical design processes for both pavement and drainage structures are described in "Highway Design Manual of Instructions", California Division of Highways.

Pavement

It is concluded no modification need be made in our methods of design of the structural sections for the purpose of reducing damage in future earthquakes. There is no pattern of damage which suggests an approach to pavement and base design changes which would reduce damage. The structural section cannot be insulated from movements of the ground on which it rests.

Drainage

The damage to drainage facilities is not as extensive as might be expected. Any drainage structure constructed in an earthquake zone will suffer damage. It is not feasible to design the structure to withstand major earth movements.

Although no modifications are recommended in present design procedures for pavement and drainage facilities to reduce damage from potential earthquakes, there are certain measures that should be considered when a project is to be constructed in a known active zone of faulting.

Alignment and profile should be adjusted to the extent possible to reduce heights of fills and depths of cuts. Slopes should be made as flat as possible both for embankment stability and to reduce slide potential in cuts. Longer and stronger approach slabs to structures would be an advantage.

In active fault areas, consideration should be given to the use of flexible pipes or pipes with flexible couplings for both cross drains and roadway drainage.

In all cases, the presence of any faulting within a project area should be identified, and consideration of earthquake potential should be an element of decisions on design.

C. Earthwork Design

When subjected to an earthquake, fills will crack, slump and settle. It is not economically feasible to entirely prevent this damage.

Attention and control is needed during construction to provide for removal of loose and compressible material from fill foundation areas - particularly in canyons, sidehill fills, and ravines. Continued emphasis should be placed on requiring foundation preparation on existing hillsides at the cut/fill contact.

Where weak and critically oriented bedding planes are exposed in cut slopes, more consideration should be given to laying back cut slopes to parallel the bedding planes and to the feasibility of constructing buttress fills to improve stability.

In the planning stage, careful consideration should be given to modifying facilities that must be placed in areas where the possibility of seismic activity is high. This might result in modifications of alignment or grade that will shift high fills, high cuts, and structures from the areas of greatest risk. Consideration should be given to the location of major interchanges. An effort should be made to site them outside of heavily faulted areas, and we should eliminate multi-level complex structures in favor of minimum cuts and fills when the likelihood of seismic activity is unavoidable.

CHAPTER VI

REFERENCES

VI. REFERENCES - EARTHQUAKE REPORT

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APPENDIX

I. Earthquake Charts, Milne and Davenport

II. Senate Bill 682

III. "Quake Disaster", book of earthquake photographs

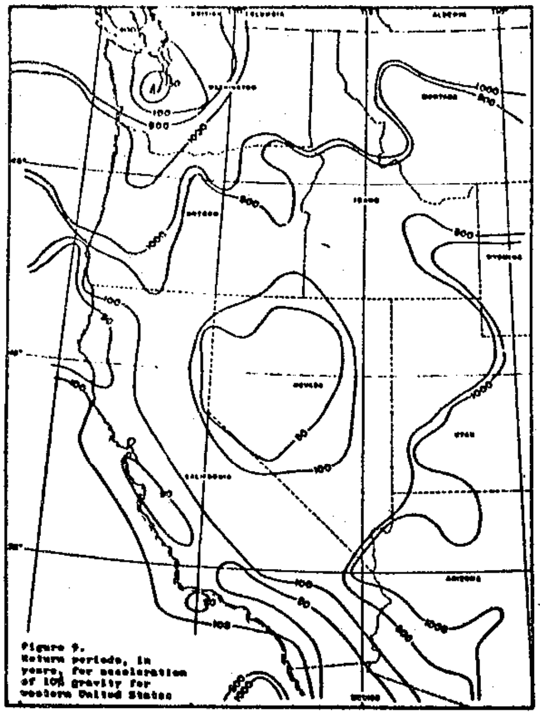

Figure 9.
Return periods, in years, for acceleration of 10% gravity for western United States

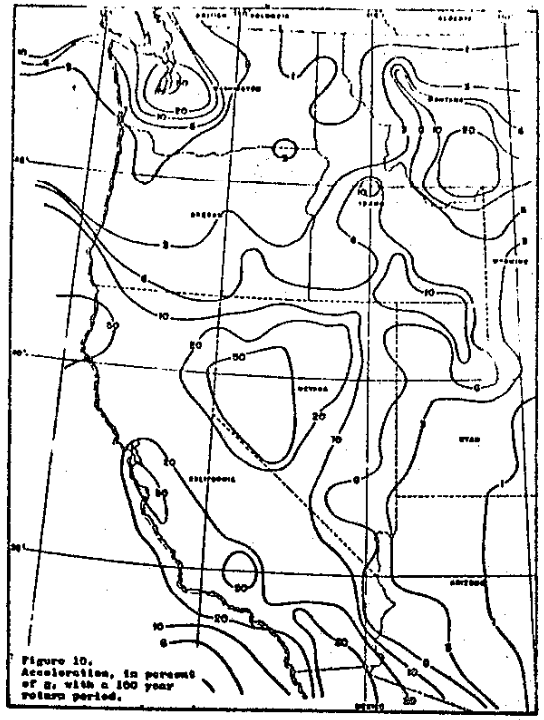

Figure 10.
Acceleration, in percent of g, with a 100 year return period.

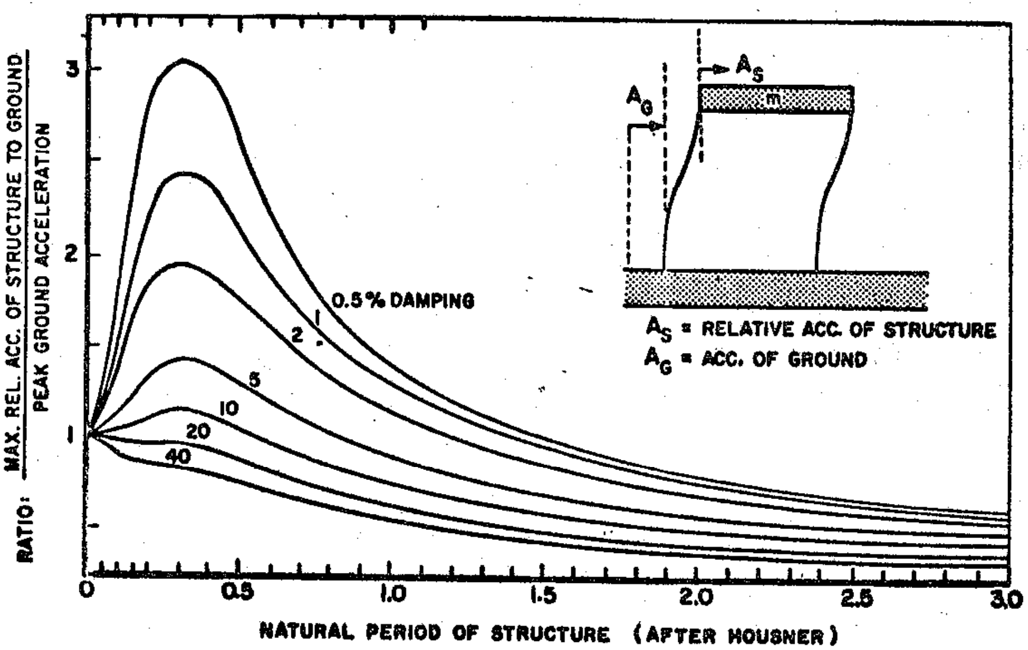

Figure 11. Earthquake acceleration response spectrum (after Housner)

Senate Bill No. 682

CHAPTER 274

An act relating to uncompleted state highway facilities damaged by earthquake, and declaring the urgency thereof, to take effect immediately.

[Approved by Governor July 7, 1971. Filed with Secretary of State July 7, 1971.]

The people of the State of California do enact as follows:

SECTION 1. The Legislature finds and declares as follows:

(a) Extensive earthquake damage to state highway facilities under construction in the vicinity of the City of San Fernando has created a severe obstacle to public traffic and a continuing danger to the public welfare.

(b) The sudden earthquake action in a zone heretofore considered to be inactive requires that thorough geologic investigations be made to determine the feasibility of reconstructing the damaged work, and to determine the proper placement and construction of the highway facilities.

(c) Due to the great magnitude of observable damage, the indeterminate magnitude of concealed and subsurface damage, and the length of time which will be required for the completion of necessary investigations, the public interest and public safety would be adversely affected by an immediate attempt to resume construction.

SEC. 2. The Department of Public Works shall perform a thorough investigation of the geologic characteristics of the construction zone to ascertain the probable influence which the proximity of the earthquake fault will have upon the construction of highway facilities. Permanent reconstruction shall not be resumed before such investigation is completed.

SEC. 3. In order to prevent the performance of further construction before the completion of the necessary investigations into the sufficiency and safety of such construction, the Department of Public Works is authorized to terminate any contract for state highway construction in the vicinity of the City of San Fernando, if the work of such contract was substantially damaged or destroyed by earthquake; provided, that such termination shall be by the mutual consent of the contracting parties. Such termination shall be deemed to constitute completion of the work.

SEC. 4. The terms and conditions under which such contracts may be terminated shall be agreed upon by the contracting parties. However, it is the intent of the Legislature that the Department of Public Works be guided by the following principles in seeking to reach agreement respecting termination:

(a) The compensation received by a contractor for all work performed prior to the earthquake shall be the reasonable cost of the performance of such work as it can be reasonably ascertained without the inclusion of a profit; provided, that such cost shall not be in excess of the contract price of such work. The determination of the contract price of partially completed items of work shall be determined by apportioning such contract prices.

(b) Such termination shall not preclude payment to the contractor for work performed after the earthquake for which he would have been entitled to payment but for such termination.

(c) That the agreement of termination shall operate as a complete and final resolution of the rights of the respective parties, and as a bar to any further claims or demands between them; provided, that such agreement shall not change or affect the responsibility of the respective parties under the contract and applicable law for claims of third parties for injury to, or death of, any person or damage to property or affect the rights of third parties who are subrogated to the rights of the contractor.

(d) The Auditor General is hereby authorized and instructed to audit all financial aspects of such termination and seek from the Division of Highways such engineering representation as he may determine appropriate in order to permit expression of an opinion on the compliance with the terms of this act. Such audits shall not be so made as to delay any termination settlements hereunder and the Auditor General shall report to the Legislature not later than January 5, 1972.

SEC. 5. The Department of Public Works shall submit to the Legislature by January 5, 1972, a report on any action it has taken to preclude any necessity in the future of the Legislature having to enact legislation to authorize it to terminate construction contracts on highway projects damaged or destroyed by a natural disaster.

SEC. 6. This act is an urgency statute necessary for the immediate preservation of the public peace, health or safety within the meaning of Article IV of the Constitution and shall go into immediate effect. The facts constituting such necessity are:

Various highway facilities were destroyed, or rendered unsafe and unusable, by the earthquake of February 9, 1971. Contracts are presently in effect which call for the performance of further construction in the area of greatest damage. Such contracts must either be performed or they must be terminated. It would be contrary to the public interest to continue to perform such contracts before the full extent of subsurface damage has been ascertained, or before a full investigation has been made into the geologic instability of the area, the risk of further earthquakes, and the type of construction which may be required to resist such earthquakes. The Legislature has determined that the public interest would be best served by an immediate termination of such contracts, but there is no administrative procedure presently in effect pursuant to which such termination may be accomplished.

Therefore, it is necessary that this act go into immediate effect.

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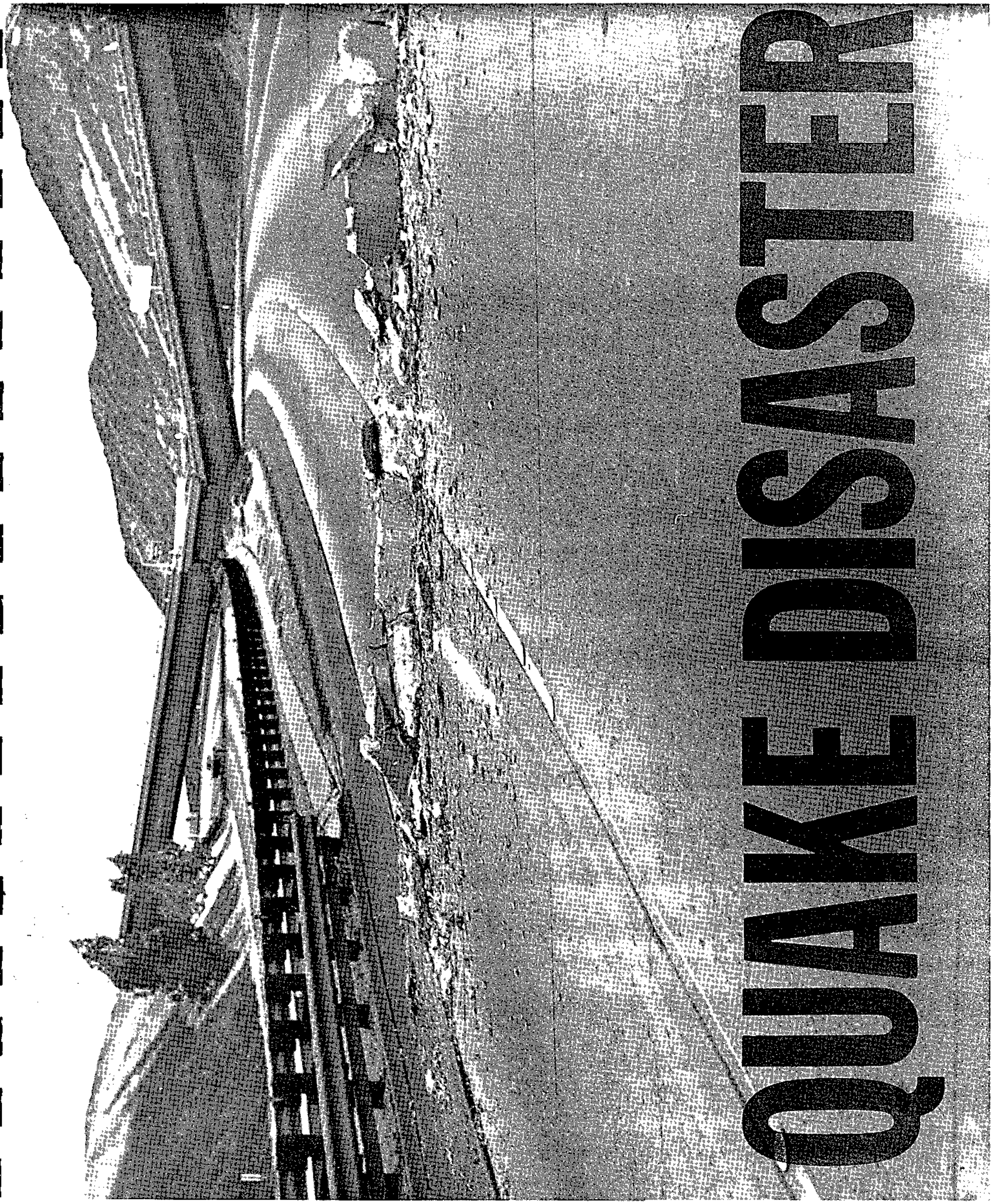
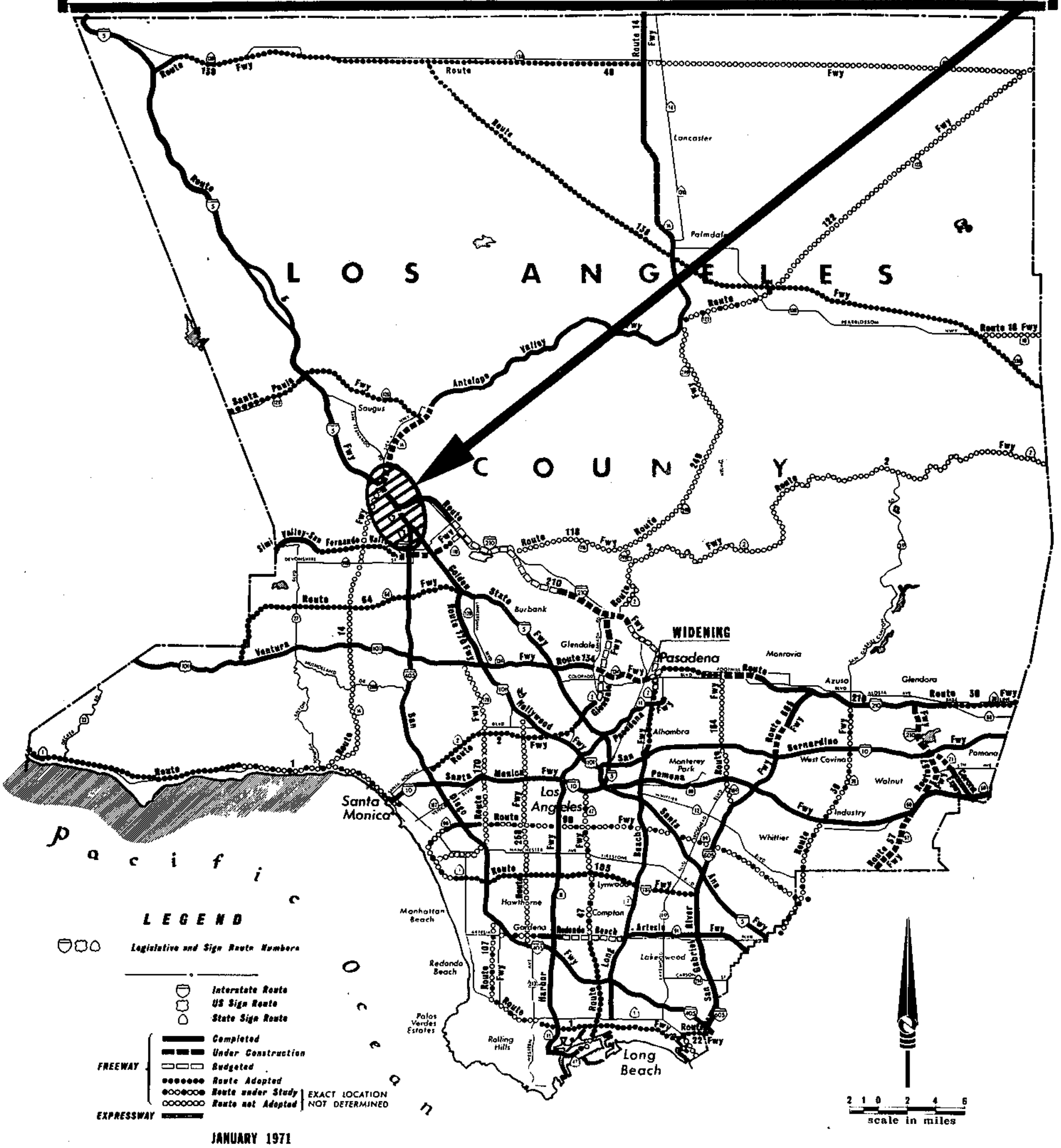
Appendix III

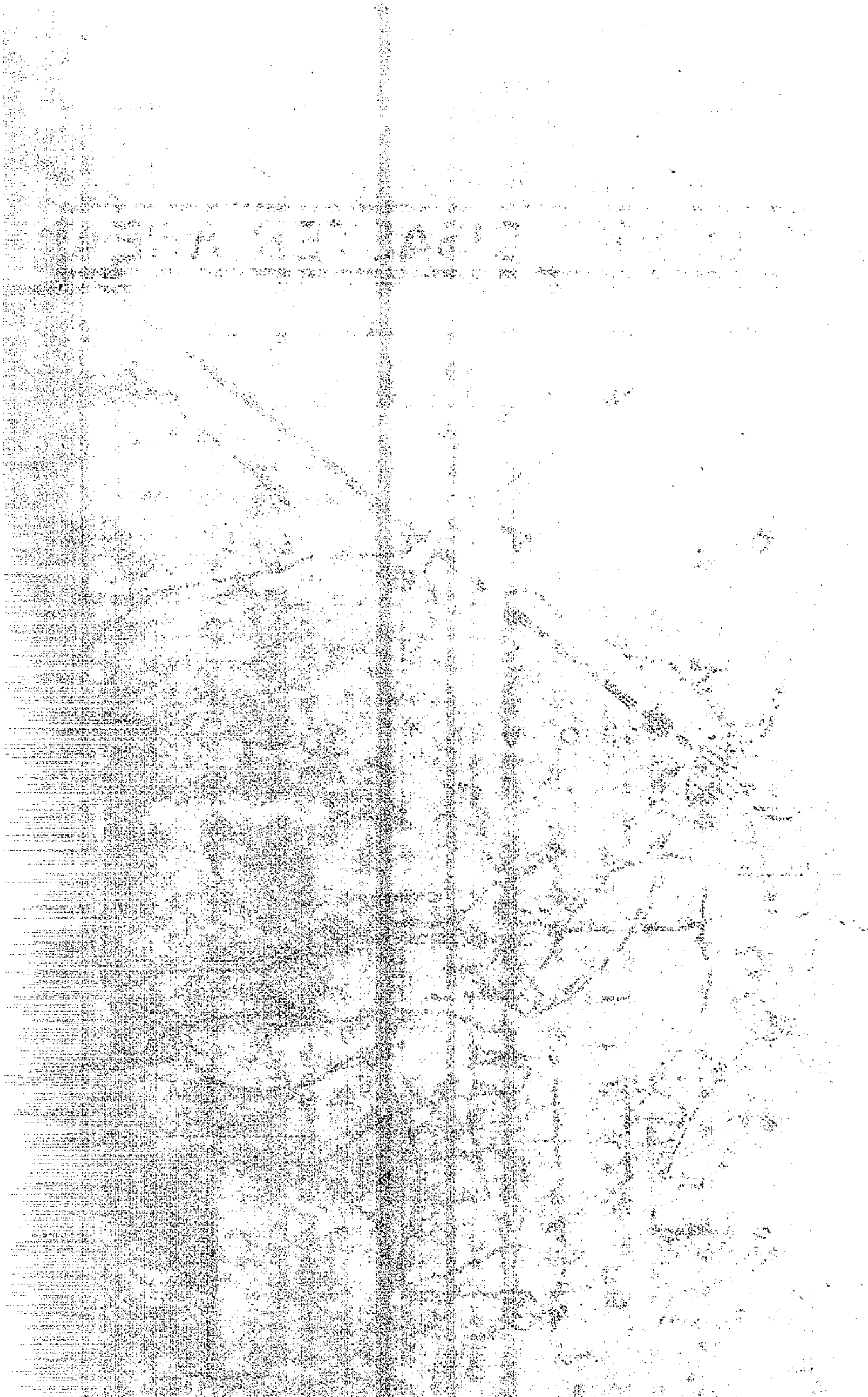


CALIFORNIA FREEWAY AND EXPRESSWAY SYSTEM

LOS ANGELES COUNTY

FREEWAY QUAKE DISASTER AREA





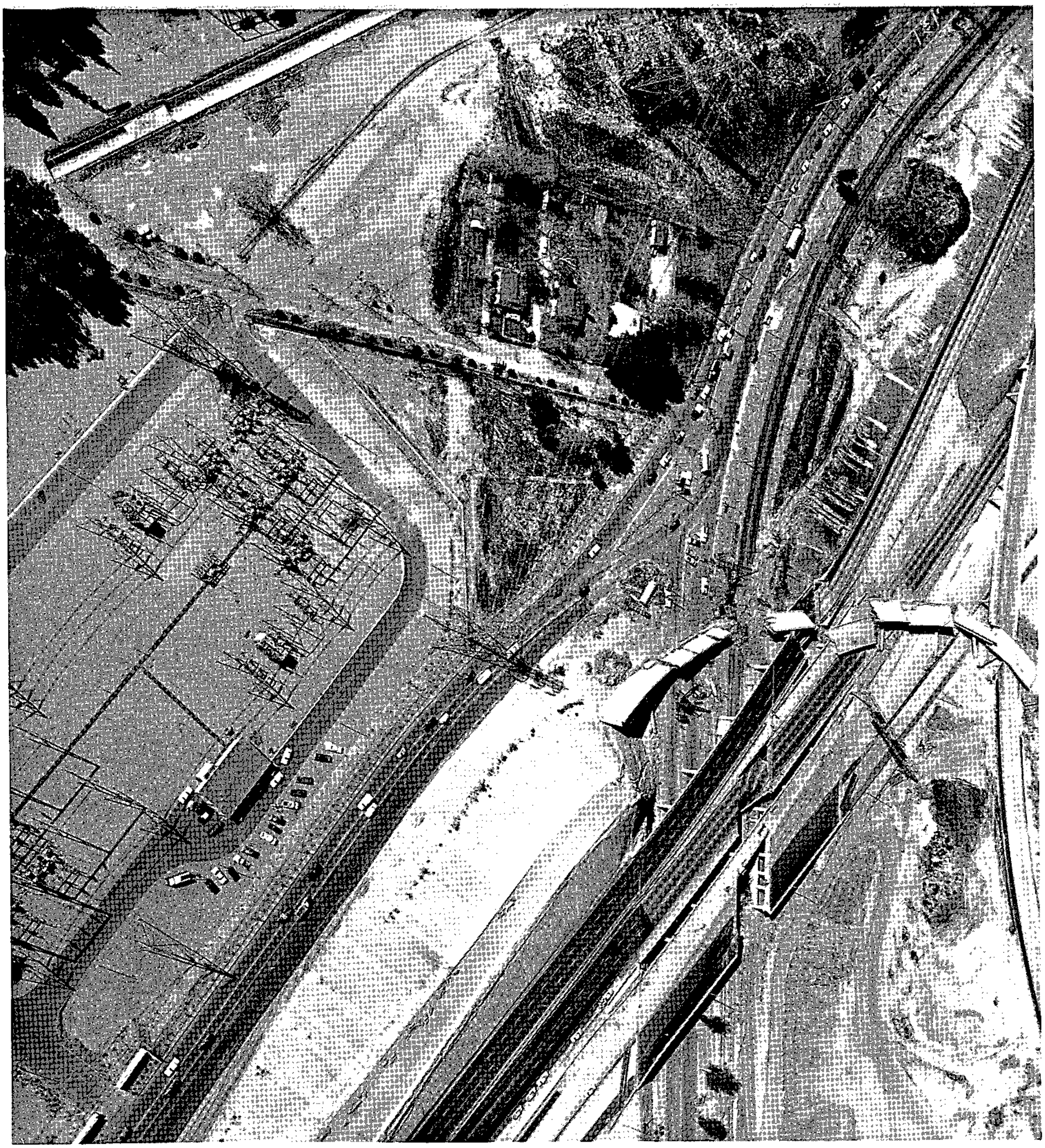
PICTORIAL BRIEF

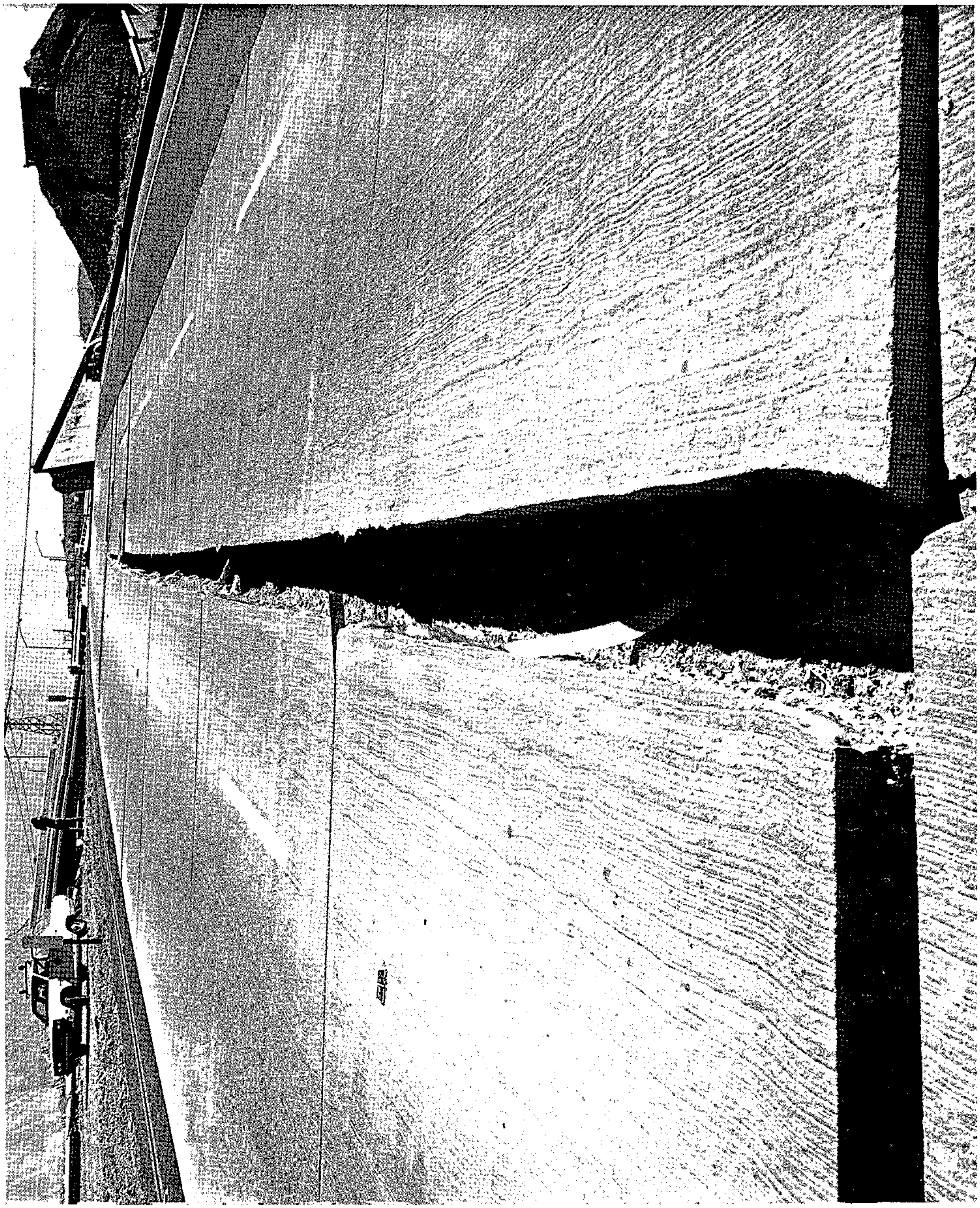
QUAKE DISASTER AND DAMAGE TO STATE FREEWAY SYSTEM

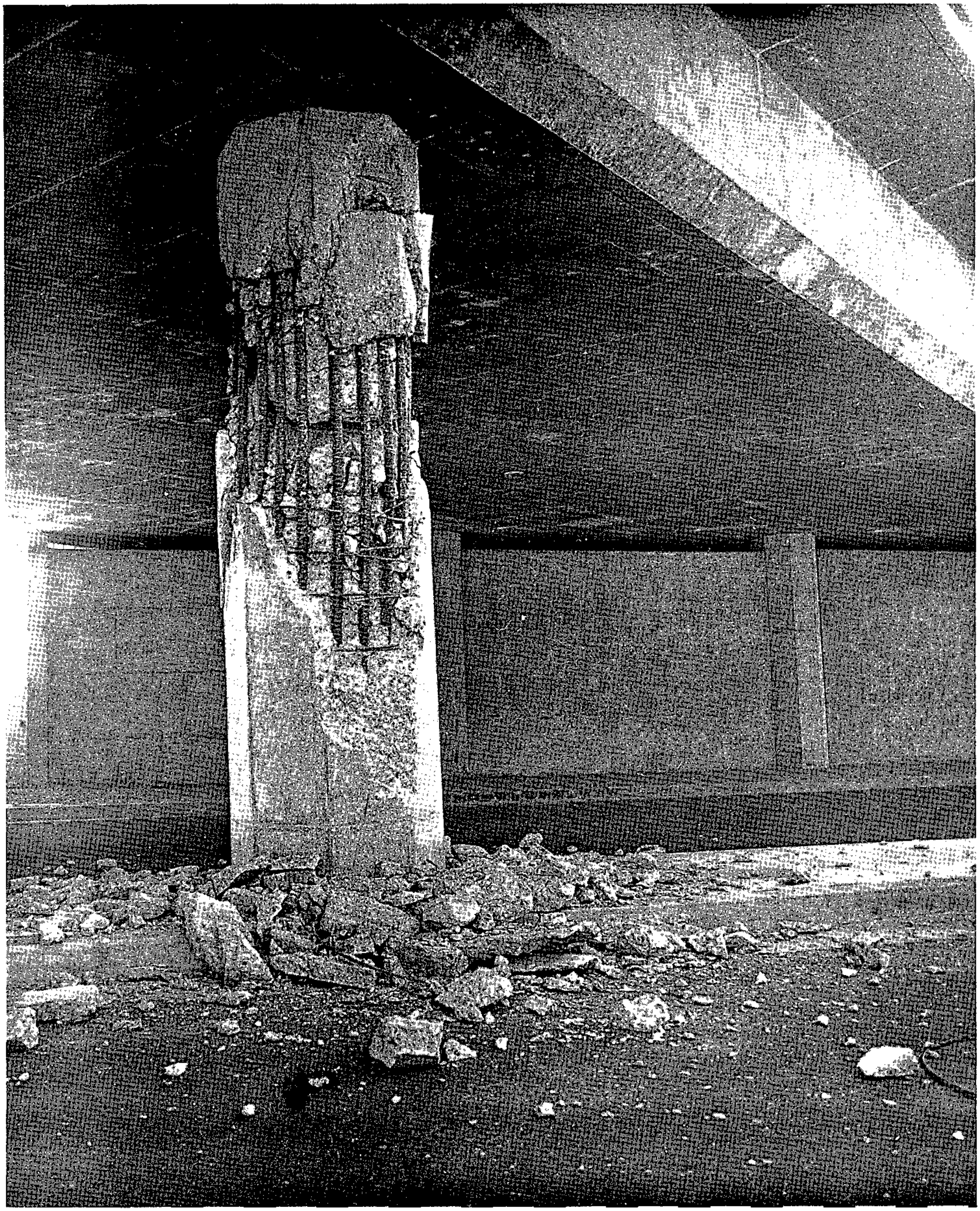
James A. Moe, Director of Public Works
State of California

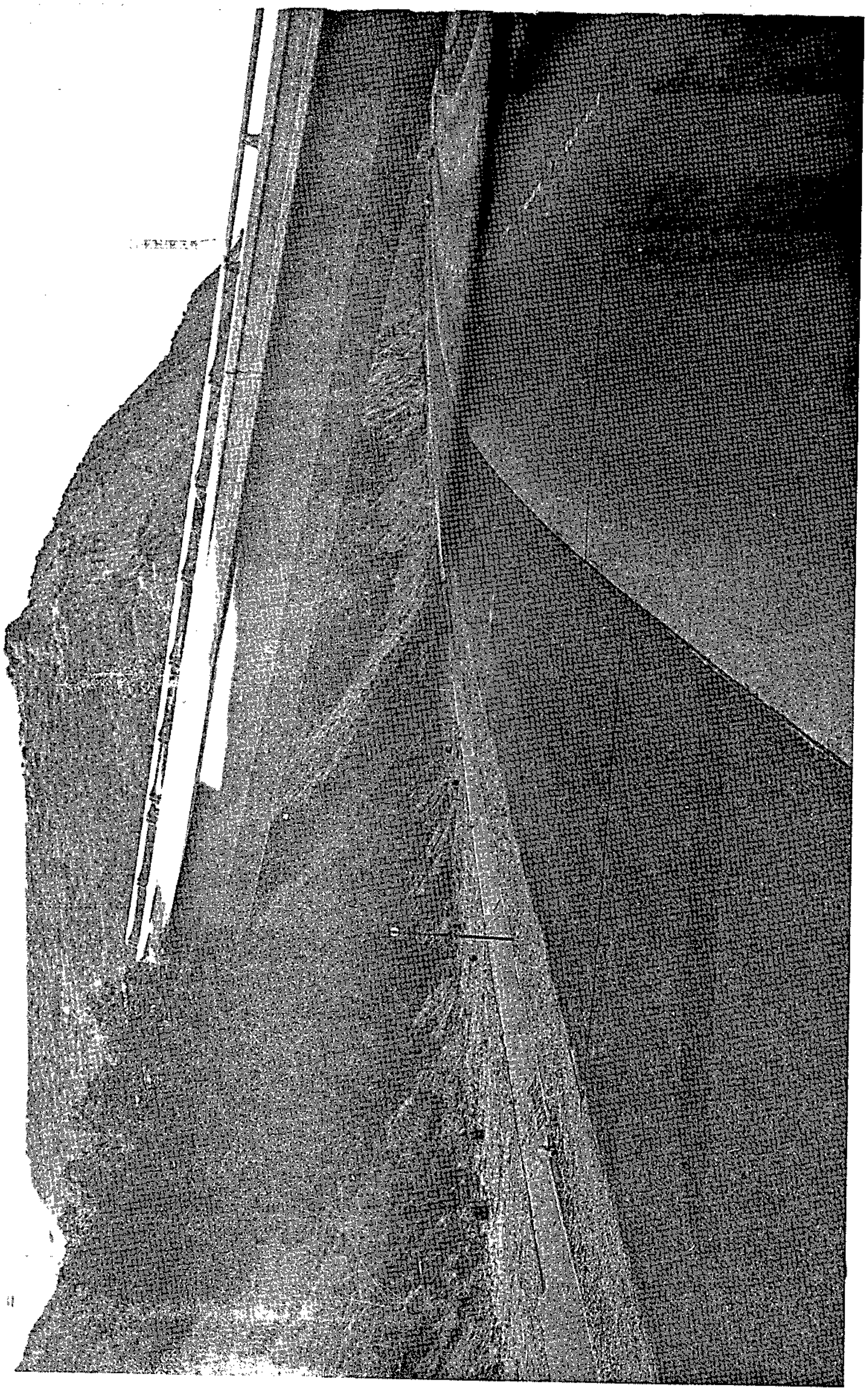
Haig Ayanian, District Engineer
District 07
California Division of Highways

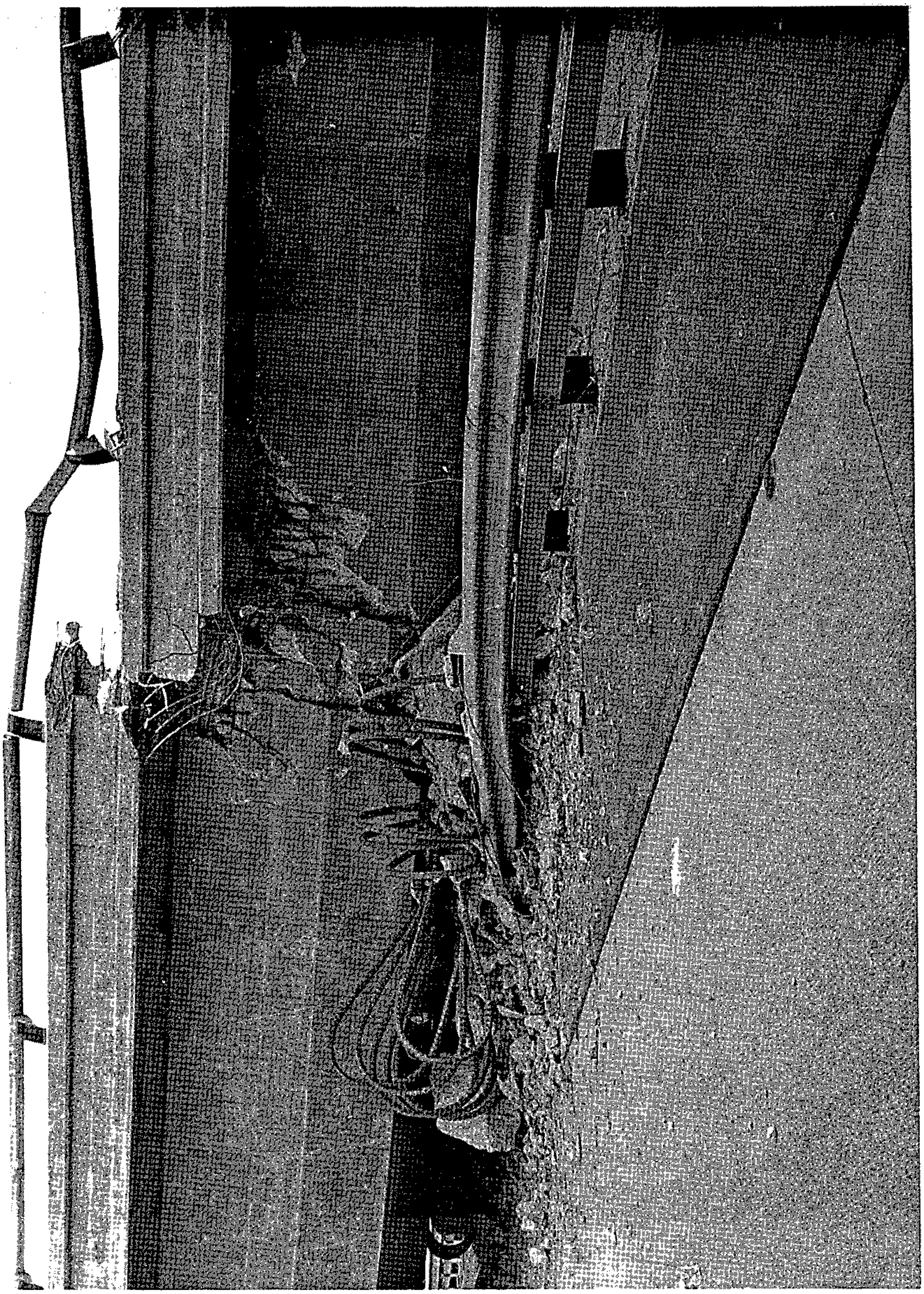
Los Angeles, California
February, 1971

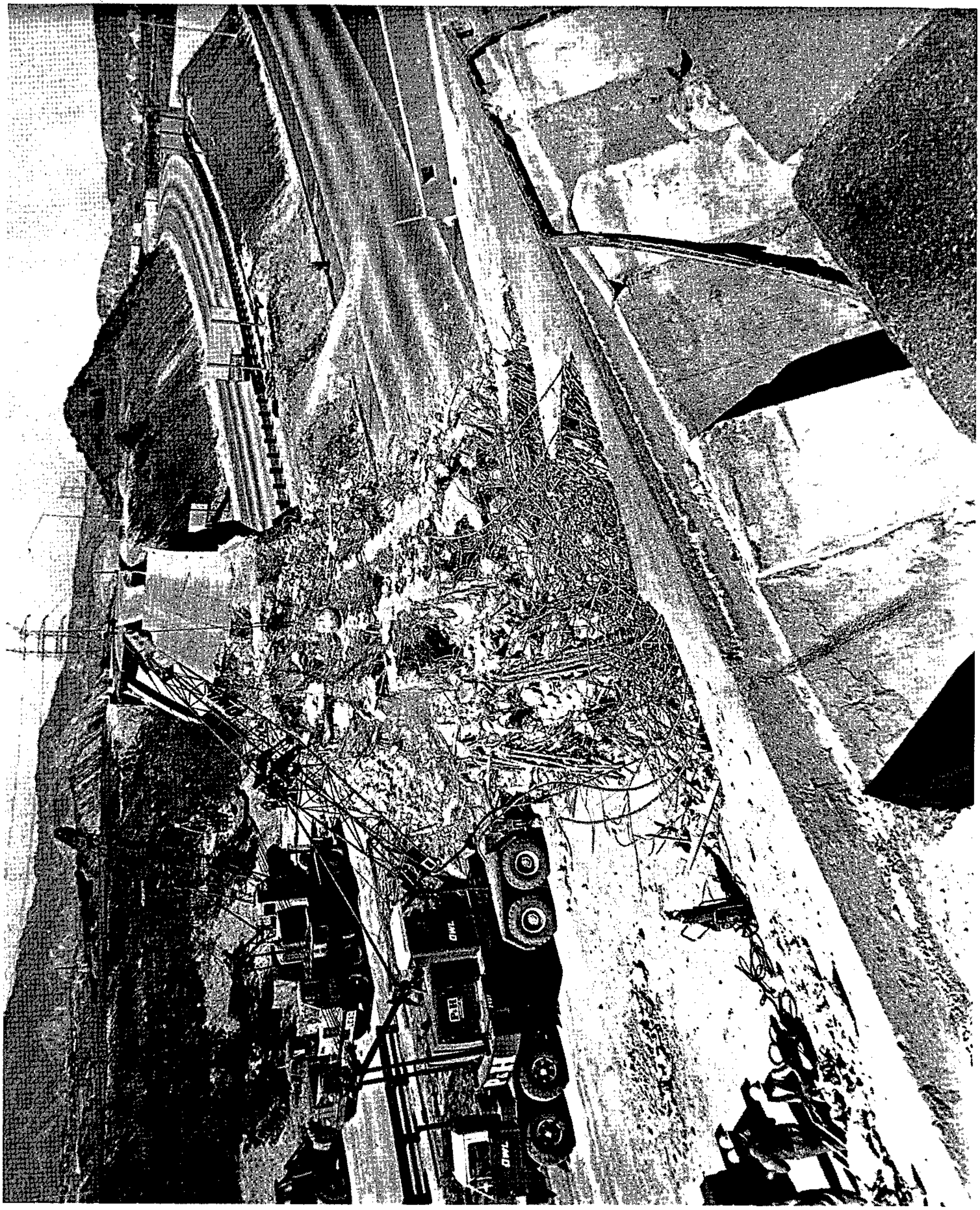


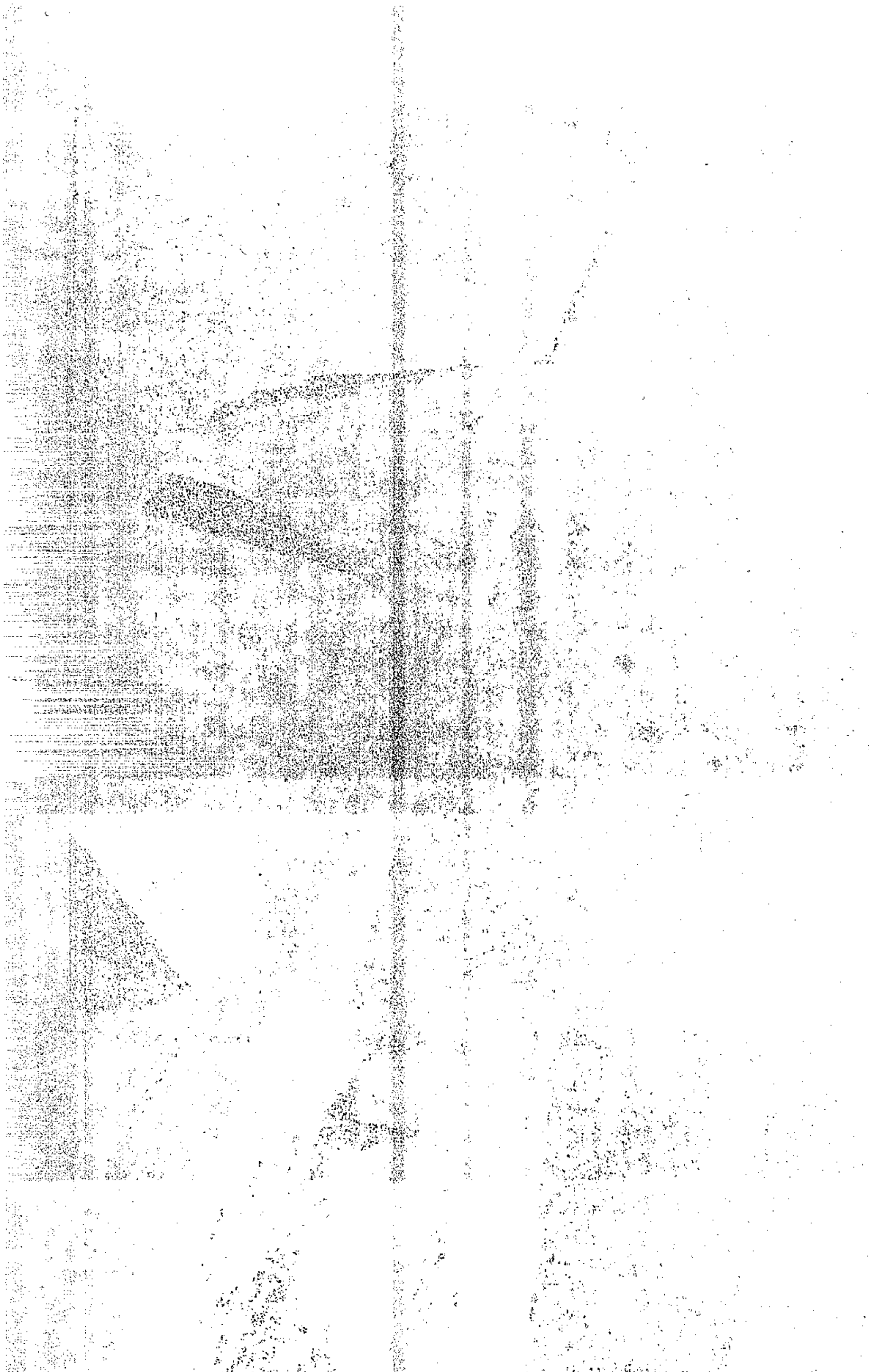


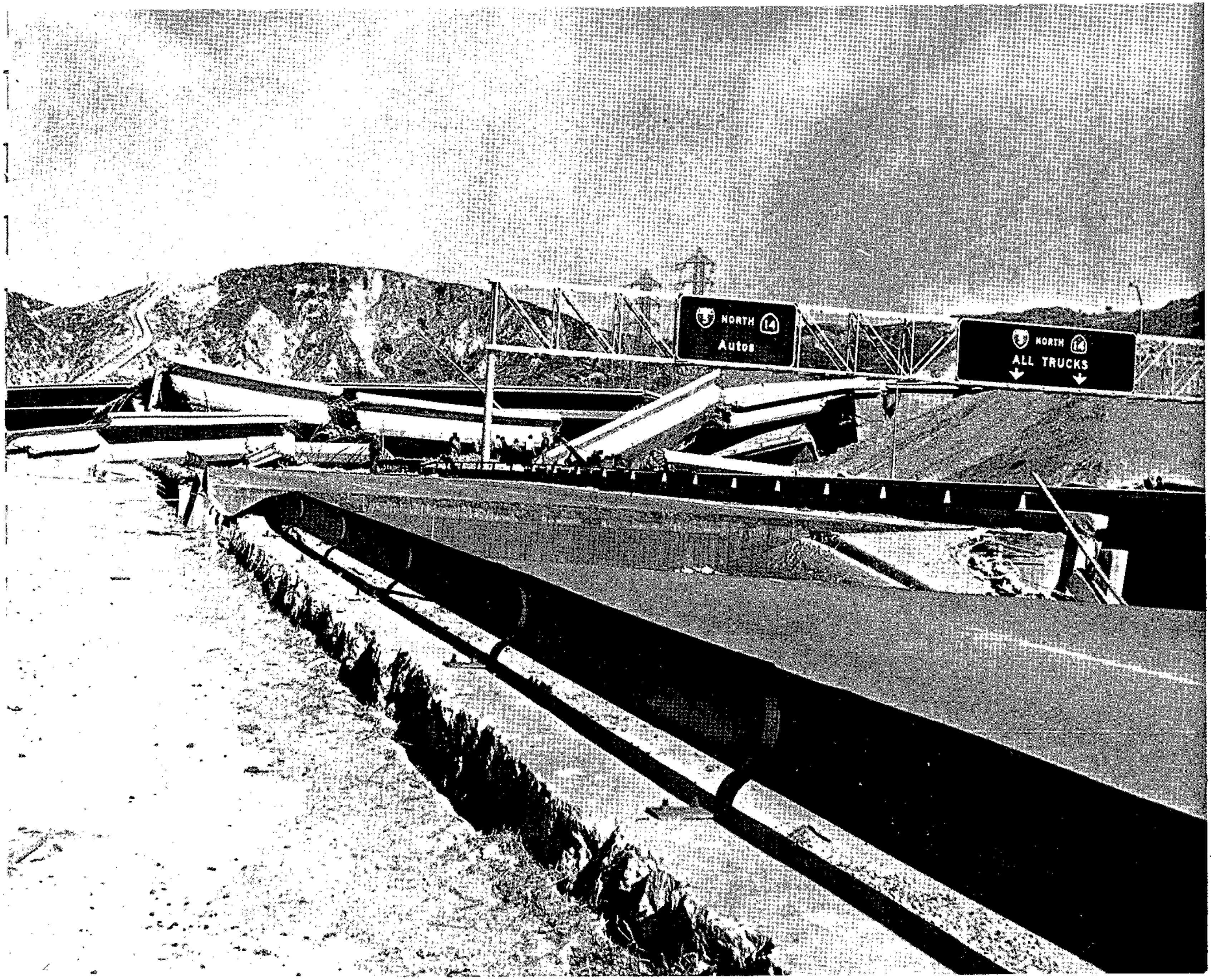












NORTH 14
Autos
NORTH 14
ALL TRUCKS